CRASH PULSE ANALYSIS USING EVENT DATA RECORDERS

Dainius J. Dalmotas
Alan German
D.J. Dalmotas Consulting, Inc.

Jean-Louis Comeau
Transport Canada

Abstract

Many vehicles equipped with air bags also have on-board crash recording systems that, in the event of a frontal collision, capture information relating to the crash, and the deployment of safety systems such as seat belt pretensioners and air bags. Typically, event data recorders (EDR) store details of the collision itself, such as the crash pulse, seat belt pretensioner and air bag firing times, and also certain pre-crash data elements such as vehicle speed, throttle and brake application, and seat belt use status. For a number of years, collision investigators have been able to download the data stored in many General Motors and Ford vehicles through the use of a crash data retrieval tool. Such records provide an opportunity to gain a better understanding of the parameters related to real-world collisions as they afford access to objective crash data with known levels of uncertainty. The current work uses EDR information from in-depth investigations of real-world collisions in Canada. Frontal impacts are categorized by crash type and severity. The resulting subsets of crash pulses and restraint system activation times are compared to data captured as part of staged crash tests that have been undertaken for both regulatory purposes and research. This provides considerable insight into the utility of regulatory crash tests and the nature of the compliance strategies adopted by vehicle manufacturers.

Résumé

Beaucoup de véhicules équipés de coussins gonflables comportent également un système d'enregistrement de collisions qui, dans le cas d'une collision frontale, saisissent des renseignements sur celle-ci et sur le déclenchement des systèmes de sécurité, comme les prétendeurs de ceinture de sécurité ainsi que les coussins gonflables. Habituellement, les enregistreurs de données de conduite (EDC) enregistrent les détails de la collision, comme l'impulsion de collision, le moment du déclenchement du prétendeur de ceinture de sécurité et du coussin gonflable, en plus de certains éléments d'information précédant la collision, tels que la vitesse du véhicule, l'utilisation de l'accélérateur et l'application des freins ainsi que l'état de l'utilisation de la ceinture de sécurité. Depuis plusieurs années, les enquêteurs sur les collisions peuvent télécharger les données enregistrées dans de nombreux véhicules de General Motors et de Ford au moyen d'un outil d'extraction de données de collision. De tels enregistrements permettent de mieux comprendre les paramètres liés aux collisions réelles puisqu'on peut accéder à des données de collision objectives avec des niveaux d'incertitude connus. Actuellement, on se sert des renseignements de l'EDC obtenus à la suite d'enquêtes approfondies sur des collisions réelles qui surviennent au Canada. Les collisions frontales sont catégorisées selon le type de collision et la gravité. Les sous-ensembles d'impulsions de collision et du

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   1

moment d'activation des ensembles de retenue qui en résultent sont comparés aux données saisies lors des essais de collision entrepris aux fins de réglementation et de recherche. Cette comparaison donne des éclaircissements importants quant à l'utilité des essais de collision aux fins de réglementation et à la nature des stratégies de contrôle adoptées par les fabricants de véhicules.

INTRODUCTION

Event data recorders (EDR) are crash recording systems installed in many vehicles as part of the sensing and control modules used to identify the need for and to initiate air bag deployment. EDR's were introduced into production vehicles in numbers by General Motors in the 1990's [1], and a crash data retrieval (CDR) tool was subsequently made commercially available by Vetronix Corporation (now Bosch Diagnostics) [2].

The CDR tool has made it possible for collision investigators to download and analyze the data captured by EDR's in real-world crashes. In General Motors' vehicles, the data so obtained can include crash pulse information, typically change in velocity (delta-V) as a function of time, air bag and seat belt pretensioner firing times, and/or a range of pre-crash data elements such as vehicle speed, throttle and brake application, and seat belt usage.

The specific data available are dependent on the vehicle year, make and model, since different vehicles are often equipped with different types of EDR's [3]. In general, late-model vehicles have more sophisticated recording systems that store a greater range of data. For example, some vehicles provide both longitudinal and lateral delta-V; deployment parameters for seat belt pretensioners and multi-stage air bag inflators; information on side air bags and head curtains; and data on pre-crash steering action.

The potential safety benefits that might accrue from the use of the information captured and retrieved from EDR's have been noted previously. For example, a working group, organized by the National Highway Traffic Safety Administration, found that EDR's could be used to improve occupant protection systems, enhance safety on the highways, reduce the number and severity of crashes through drivers' awareness of the availability of the devices and their recording capabilities, and facilitate early notification of the occurrence, nature, and location of collisions through automatic crash notification (ACN) systems [4].

The crash pulse information captured by EDR's has been shown to be reasonably accurate through comparisons of the data recorded by in-vehicle EDR's with equivalent data captured by laboratory instrumentation during staged collisions. Comeau, German and Floyd [5] evaluated data from a series of crash tests of General Motors' vehicles, conducted at various speeds and collision configurations, and found the EDR data to be generally within the stated tolerances for the devices. In some instances the EDR's were unable to capture the entire crash pulse as a result of storage limitations or power disruptions. Similar findings have been published by other authors for staged collisions involving vehicles manufactured by General Motors, Ford and Toyota. [6,7]

In both Canada and the U.S., government researchers have been early adopters of EDR technology, and have integrated the use of these devices into their in-depth collision investigation programmes. As a result, there are growing databases of real-world collisions that include detailed crash pulses and other data elements from the crash phase. The current work focuses on such data, and evaluates some the available parameters by collision type and severity, providing some insight into the performance of vehicle structures and on-board safety features in terms of the requirements of regulatory crash tests and the situation in the real world.

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   2

METHODOLOGY

Data relating to real-world crashes with motor vehicles equipped with EDR's have been compiled by Transport Canada. These EDR data have been combined with associated vehicle data in order to characterize the nature of the collisions. Measurements from staged collisions conducted by Transport Canada that have involved EDR-equipped vehicles are used as a source of reference data.

Canadian Field Data

The Canadian data used in the current work are taken from the programme of Directed Studies of real-world collisions conducted by Transport Canada. [8] The research teams, undertaking these studies across Canada, have been equipped with CDR tools since these devices became publicly available in 2000. Subject to obtaining authorization from vehicle owners, the teams routinely include information downloaded from EDR's present in collision-involved vehicles in the Directed Studies' case files. In addition, as part of the in-depth collision investigation process, data are also compiled on the collision scene, the involved vehicles, vehicle occupants, and any non-occupants (e.g. pedestrians and cyclists) involved in each crash.

For the present purposes, particularly useful datasets have been drawn from various phases of the Air Cushion Restraint Study, where cases are selected specifically on the basis of an air bag being deployed in a late-model vehicle, and with various criteria for model year defining each sample. In particular, study phases ACR4 through ACR8 were used as these are the series where data from EDR's are available. Since the EDR is integrated into the vehicle's command and control system that is used to fire the air bag, these phases of the study provide a rich source of relevant data.

Crash Test Data

Transport Canada conducts programmes of staged collisions both to support the development of new and enhanced safety regulations, and to ensure compliance with the requirements of existing Canadian Motor Vehicle Safety Standards (CMVSS). Information from a number of Transport Canada's frontal crash test programmes, involving General Motors' vehicles which were equipped with EDR's that had been subsequently downloaded, were used in the present work to provide reference data for both air bag firing times and crash pulses.

The regulated crash tests of current interest are full frontal impacts with a rigid barrier (FFRB), conducted at a nominal impact speed of 48 km/h. In particular, this collision configuration is used to monitor compliance with CMVSS 208 - Occupant Restraint Systems in Frontal Impact. For this test, fully-restrained, 50th percentile, male dummies are placed in the vehicle's front seats and their on-board instrumentation used to assess injury potential. The relatively high impact speed, and the rigid nature of the barrier, typically produce a short crash pulse with high peak deceleration values, a so-called hard crash pulse.

Many crash tests, using different dummies, collision configurations, and test speeds, have been conducted for research purposes. In particular, a programme of 40%-offset, frontal collisions into a deformable barrier (OFDB), at speeds of up to 40 km/h, and using 5th percentile female dummies, has been used to develop a test to promote the safety of occupants of smaller stature than the average male. [9] The defining nature of these impacts is the relatively long and soft acceleration pulse produced by the partial interaction of the frontal vehicle structure with the non-rigid barrier. Tests with similar offset collision configurations, but conducted at higher speed of 64 km/h, have also been used to

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   3

evaluate the test protocol that is used in the vehicle safety ratings' programmes run by Euro NCAP [10] and the U.S. Insurance Institute for Highway Safety (IIHS). [11]

Another frontal crash test programme, for which some EDR data are available, involved passenger cars impacting underride guards on the rear of simulated semi-trailers, conducted during the development of CMVSS 224 – Rear Impact Protection [12]. Because such collisions typically engage the fronts of the cars above the main structural elements, this series of crash tests provides further examples of relatively long and relatively soft crash pulses. The tests also provide examples of "harder" crashes, given more complete engagement of the vehicle and the underride guard structure.

Data Reduction

A large majority of the real-world crashes involve information from EDR's in General Motors' vehicles and, in order to achieve the greatest measure of consistency with respect to the available data elements, the current work has been restricted to this single manufacturer. Furthermore, focus has been placed on the EDR record of the crash phase of any given collision and, in particular, on the air bag firing time and the crash pulse.

The air bag firing time is provided as the time between algorithm enable (AE) in the vehicle's sensing and diagnostic module (SDM), and the point at which a command to the vehicle's air bags is issued. Algorithm enable is the point at which the vehicle's deceleration pulse is of the order of 1 to 2 g, such that the SDM commences detailed monitoring and analysis of the crash data. [1] If the SDM's algorithm determines that the initial crash situation warrants air bag deployment, then a firing command is issued. At this point, the air bags will be deployed, provided that any other necessary conditions are met, such as the vehicle's safing sensor being closed.

In General Motors' vehicles, the crash pulse is recorded as the vehicle's cumulative change in velocity (delta-V) in 10 ms increments. The data may range over a 150-300 ms period, depending on the specific model of the vehicle's SDM, and the nature of the crash. Most early vehicles took measurements from a single, longitudinal accelerometer and computed the associated delta-V data. Many recent models are equipped with both longitudinal and lateral accelerometers and thus provide delta-V along both the x- and y-axes.

For our present purposes, the EDR data have been combined with associated vehicle and damage data in order to characterize the nature of the collisions. Vehicle year, make and model are used to classify the vehicle type, while Collision Deformation Classification (CDC) codes allow categorization of the nature of the crash. [13]

RESULTS

The data have been selected based on the availability of the air bag firing time, and partitioned with regard to the air bags having either single-stage or dual-stage inflators. This provides a sample with a total of 211 EDR records, comprising 118 vehicles equipped with single-stage air bags and 93 vehicles equipped with dual-stage air bags.

As would be expected, based on CDC, the vast majority (87%) of the impacts are to the front of the vehicle. Furthermore, most of these frontal crashes (95%) have PDOF's of either 11, 12 or 01 o'clock. Only 5% of the frontal crashes have PDOF's of either 10 or 02 o'clock. Collisions to the left and right sides of the vehicle constituted a minority (13%) of the air bag deployment sample. Most of the left-side

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   4

impacts involved PDOF's of either 10 or 11 o'clock, while most of the right-side impacts had PDOF's of either 01 or 02 o'clock.

In angled-frontal and angled-side impacts, the existence of substantial longitudinal components of the principal force, sufficient to deploy an air bag, might well be expected. Since in our current sample, the frontal air bags in the subject vehicles did deploy, we can conclude that the longitudinal component of the principal direction of force in each case was indeed sufficient to cause the air bag to be fired.

The availability of data from EDR's installed in vehicles involved in real-world crashes provides the opportunity to study the manner in which air bag systems in such vehicles are deployed. In particular, we can examine the time taken for the decision to command air bag deployment, and the nature of the crash pulse, over a wide range of crashes.

Air Bag Firing Times

Figure 1 shows the range of firing times for single-stage air bags for a number of 48 km/h frontal rigid barrier crash tests and for the real-world crashes in the sample that were equipped with such air bags.

The striking feature of this chart is the extremely small overlap in the firing times. The average firing time for the staged collisions was 6.7 ms, while that for the field collisions was 32.9 ms. In addition, quite a number of real-world crashes produced firing times in excess of 60 ms, with a few vehicles having extremely long firing times of above 80 ms. These latter cases typically involved soft impacts, such as narrow frontal engagement with roadside barriers and frontal underride in rear-end collisions. The maximum delta-V for these crashes was often below 32 km/h (20 mph) and the time to reach maximum delta-V frequently above 150 ms.

In Figure 2, we can see the range of air bag firing times for the 48 k/h frontal rigid barrier crash tests compared to the times observed in two other types of staged collisions. Four crash tests involved 1998 Chevrolet Cavaliers striking rear underride guards on simulated semi-trailers. Two of these tests were conducted with an impact speed of 48 km/h, while two had an impact speed of 65 km/h. The remaining tests were all 40 km/h, 40% offset, frontal crashes into deformable barriers. Three of these tests involved 1998 Chevrolet Cavaliers while the fourth test was of a 1999 Chevrolet Malibu.

The two 65 km/h crashes with the rear underride guards each produced firing times of 12.5 ms, comparable to the 10 ms observed as the upper limit for the firing times in the rigid barrier tests. The 48 km/h underride crash tests had firing times in the range 19-21 ms, similar to the lower bound seen in the series of 40 km/h frontal offset tests using a deformable barrier.

The frontal offset crash tests had widely varying air bag firing times, ranging from 21 to 85 ms. Two of the crashes had firing times in the range 32-34 ms, comparable to the average firing time for the sample of real-world collisions. The 85 ms firing time, observed in the offset crash test with the 1999 Chevrolet Malibu was similar to the highest firing times seen in the real-world collisions.

A similar situation with respect to the air bag firing times observed for single-stage air bags was seen in the data obtained for dual-stage air bags, in both the real-world collisions, and in the 48 km/h full frontal rigid barrier crash tests. For 23 rigid barrier crash tests with dual-stage air bags, the average firing time was 10.5 ms over a range of 2.5 to 16.0 ms. The average firing time for the field collisions involving dual-stage air bags was 29.7 ms, with the range extending from 5 to 96 ms.

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   5

Range of Airbag Fire Decision Times Observed in Crash Tests and Field Collisions
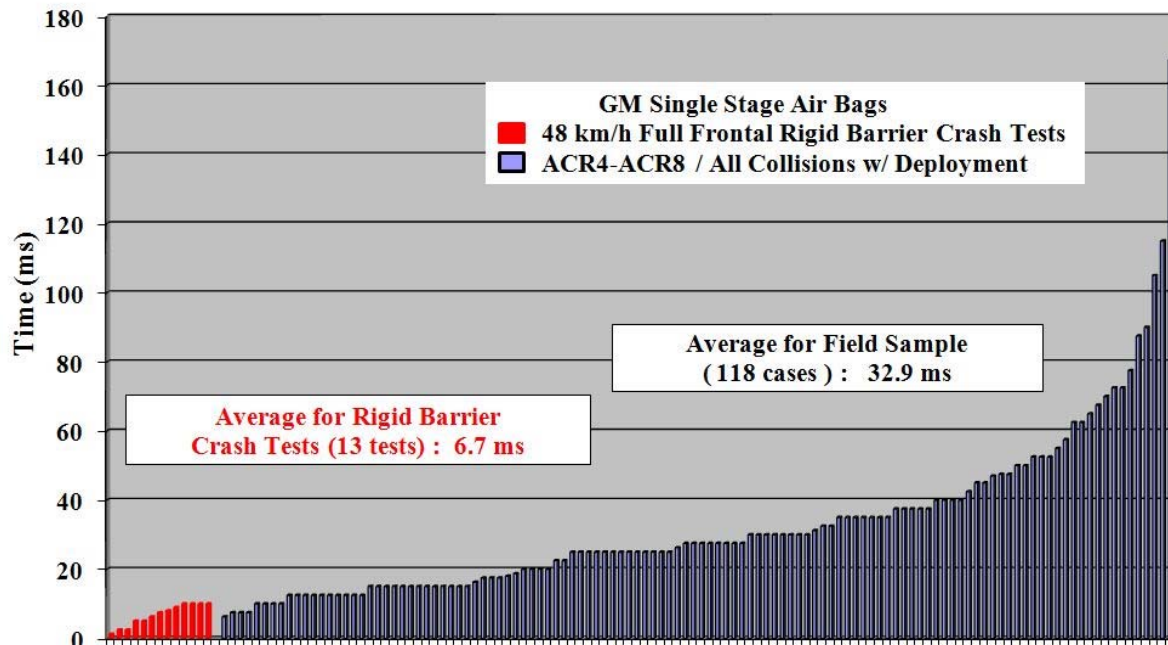

Figure 1. Range of Air Bag Fire Decision Times

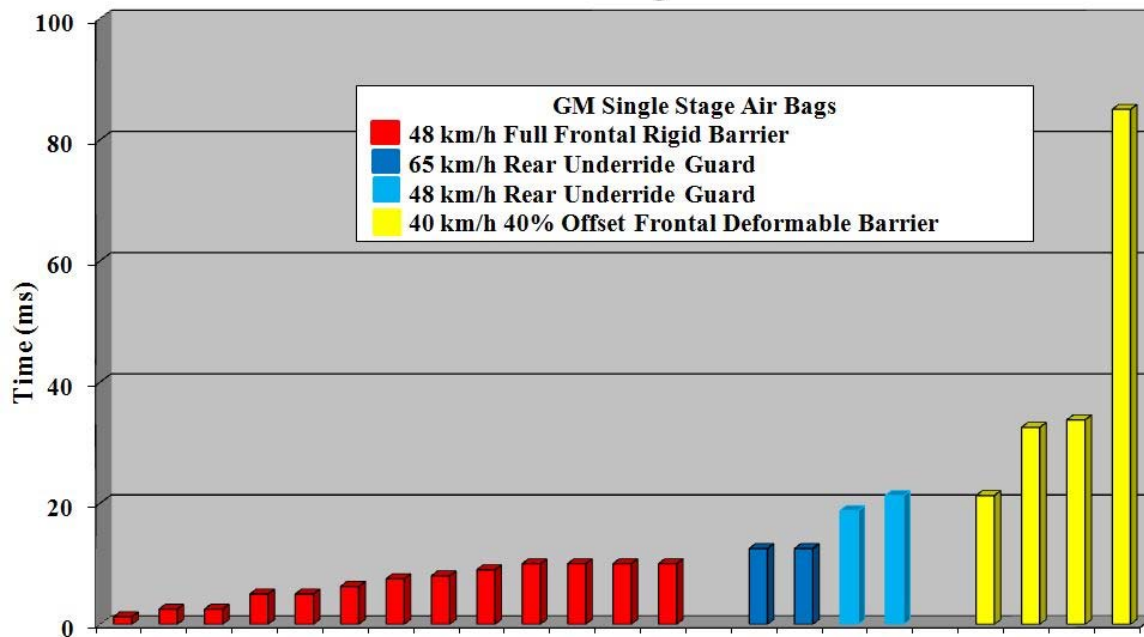## Range of Airbag Fire Decision Times Observed in Staged Collisions

Figure 2. Air Bag Fire Decision Times in Staged Collisions

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009

6

Crash Pulses in Staged Collisions

The delta-V versus time plots for the series of 48 km/h full frontal rigid barrier tests with single-stage air bags are shown in Figure 3. Plots for the 40 km/h offset front deformable barrier crash tests, and the 48-65 km/h rear underride guard crash tests, are shown in Figure 4. Similar crash pulses were obtained for dual-stage air bag systems; however, space does not permit inclusion of these data here.

It should be noted that there are some timing issues with the EDR records. In particular, even though a crash into a rigid barrier typically generates a rapid onset in the vehicle's deceleration, the pulse for certain vehicles can show a distinct time shift in the delta-V trace to the right, as a result of the initial values of delta-V (i.e. for t=10, 20 ms, etc.) being recorded as zero. [7] In the current plots, the time series have been modified to eliminate any such effects.

It is also worth noting that some EDR's record the crash pulse over a period of 300 ms and can capture the entire collision event. Other EDR's involved in this series of tests have recording buffers that are more limited, often to a range of just 150 ms and, while most of the rigid barrier crash pulse is captured, frequently the rebound phase of the collision is not recorded.

In Figure 4, the "200 series" (e.g. TC98-212, TC98-213, etc.) are from the four 40 km/h frontal offset deformable barrier crash tests, while the "500 series" (e.g. TC98-501, TC98-502, etc.) are for the collisions into semi-trailer underride guards. The crash pulses for the offset deformable barrier tests are very similar in nature, while those for the underride guard collisions are more diverse.

While the rigid barrier tests shown in Figure 3 have crash pulses that span over approximately 100 ms, the offset deformable barrier crash pulses extend over more like 150 ms, and have a shallower slope. The crash pulses for the underride guards are much more variable, both in terms of pulse shape and the ultimate delta-V. The larger delta-V exhibited in two of the crashes results from the higher test speed (65 km/h) used.   The shape of the crash pulse undoubtedly results from different geometries and materials used in the construction of the underride guards used in the research programme.

In particular, it is clear that one guard (TC98-507) provided considerably more resistance to penetration than did the others, and yielded a crash pulse signature more like that of a rigid barrier test. Also, the crash pulse from TC98-502 is interesting in that around t=80 to 100 ms the vehicle's deceleration profile flattens out completely, suggesting that a portion of the guard structure was yielding and offering very little resistance. Subsequently, the crash pulse continues its generally downward trend, indicating that vehicle-guard engagement had once again attained a resistive path.

Crash Pulses in Real-World Collisions

The subset of crash pulses recorded for single-stage air bag equipped vehicles involved in real-world collisions, where the change in velocity was 40 km/h (25 mph) or greater, is shown in Figure 5. Given that the entire series of crashes is comprised of 118 separate vehicles, it is clear that collisions more severe than the regulated 48 km/h (30 mph) frontal rigid barrier test are few in number. A similar situation exists for the subset of vehicles equipped with dual-stage air bags that are contained within the present sample.

Nevertheless, collisions of considerably greater severity do occur, For example, the crash pulse for Case No. ACR6-1202, shown in Figure 5, indicates that the subject vehicle experienced a maximum delta-V of 89 km/h (55 mph). This was the result of a head-on collision between a full-size and a

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   7

Delta-V Time Histories Observed in Staged Collisions
GM Single Stage Airbags / Staged Full Frontal Rigid Barrier @ 48 km/h (30 mph)

Figure 3. Crash pulses for 48 km/h (30 mph) full frontal rigid barrier tests

Delta-V Time Histories Observed in Staged Collisions
GM Single Stage Airbags / Staged Offset Frontal & Underride Tests
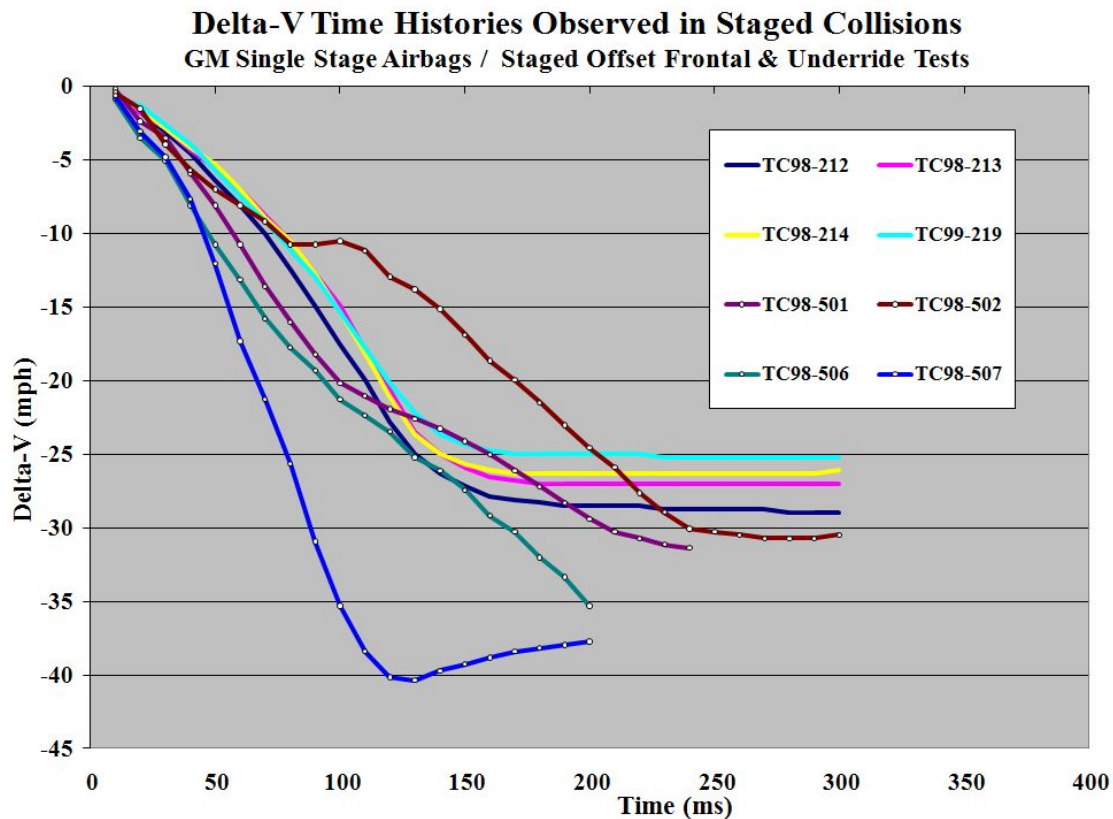

Figure 4. Crash pulses for 40-65 km/h (25-40 mph) offset frontal deformable barrier and rear underride guard tests

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference, Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière, Saskatoon, Saskatchewan, 8-10 juin 2009

8

compact pickup truck, both initially travelling at highway speeds. In the collision, a 1999 Chevrolet S-10 pickup truck was driven rearwards by a larger 2002 Chevrolet Silverado K2500 pickup truck and sustained the greater delta-V of the two vehicles.

The crash pulses for two collisions, ACR7-1907 and ACR6-1619, are notably less steep and of longer duration than the majority of the cases shown in Figure 5. Both of these crashes involve the front of the subject vehicle making contact with the side of the struck vehicle. While the impact speeds were high, hence the large maximum delta-V's, the relatively soft side structures of the struck vehicles moderated the deceleration of the subject vehicles.
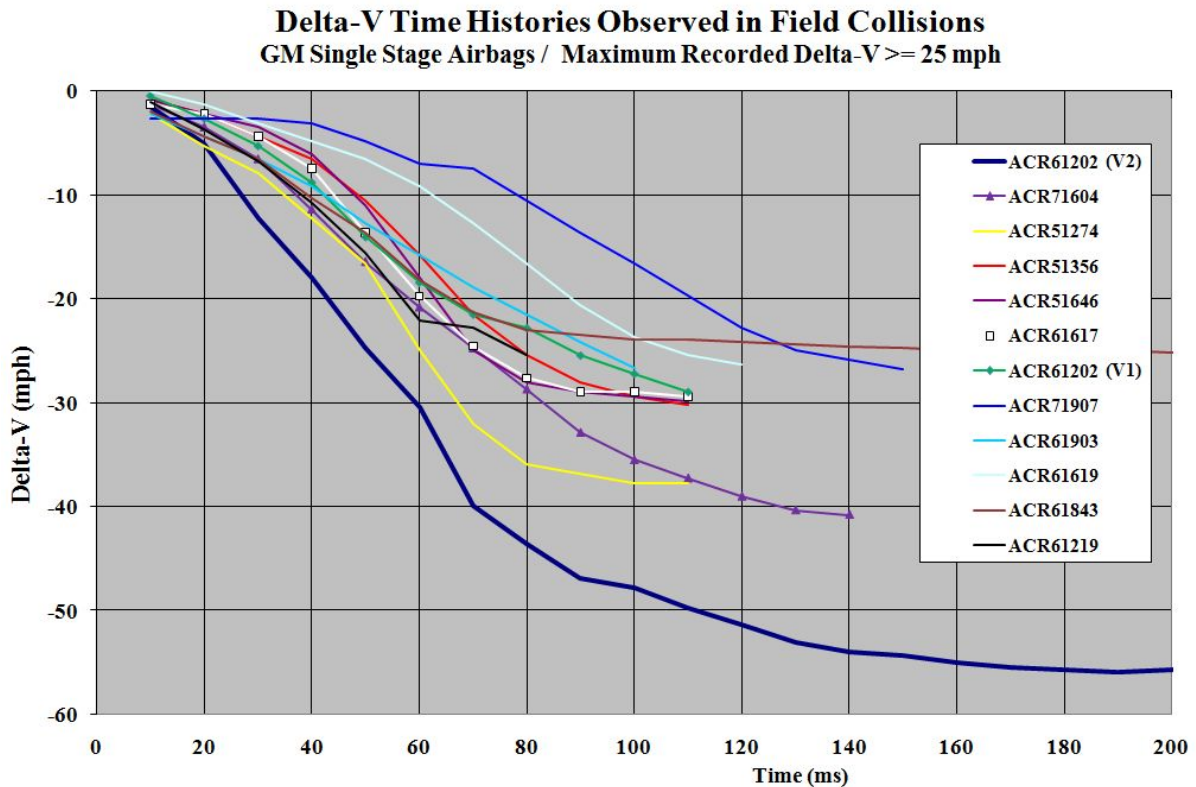

Figure 5. Crash pulses recorded in real-world collisions
where delta-V ≥ 40 km/h (25 mph)

Case Studies

The availability of EDR's in production vehicles and, in particular, their ability to capture real-world crash pulses, provides us with an opportunity to identify collisions that are similar in nature to regulated crash tests. The following two case studies provide such examples. The first crash is similar to the 48 km/h frontal rigid barrier test (Figure 6). The second collision closely approximates a 40 km/h, 40% offset, frontal collision with a deformable barrier (Figure 7). The latter test configuration was developed by Transport Canada to promote the safety of occupants of small stature [9], and has been adopted as part of the U.S. Federal Motor Vehicle Safety Standard 208 [14].

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   9

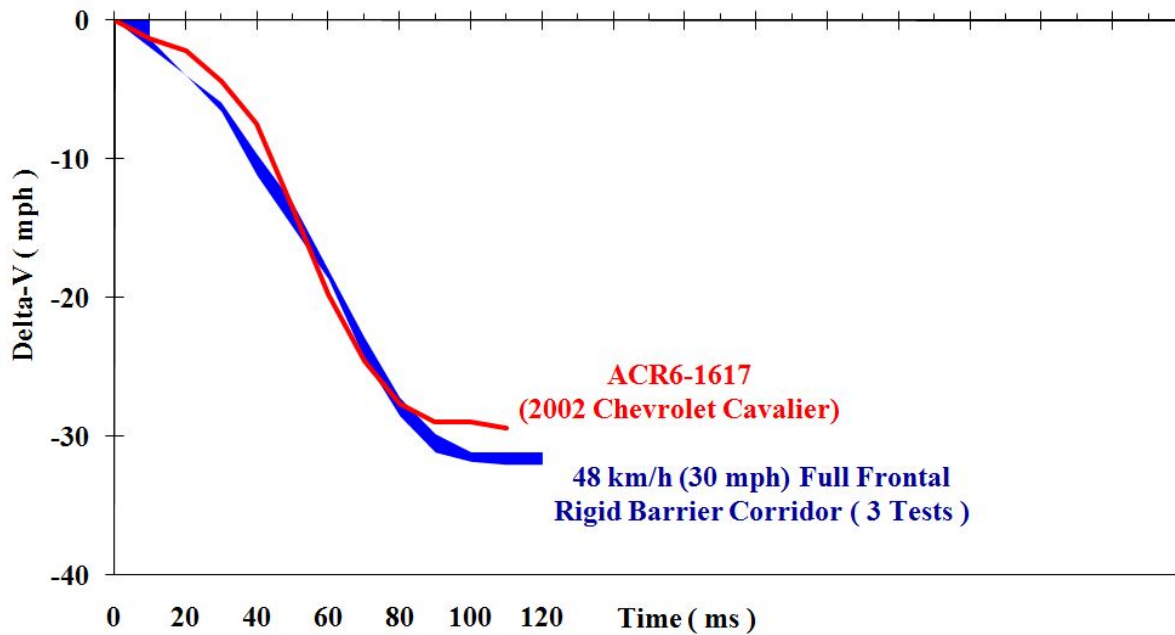**Full Frontal Rigid Barrier Crash Tests**

**Figure 6. Comparison of a real-world crash pulse with
48 km/h frontal rigid barrier tests**
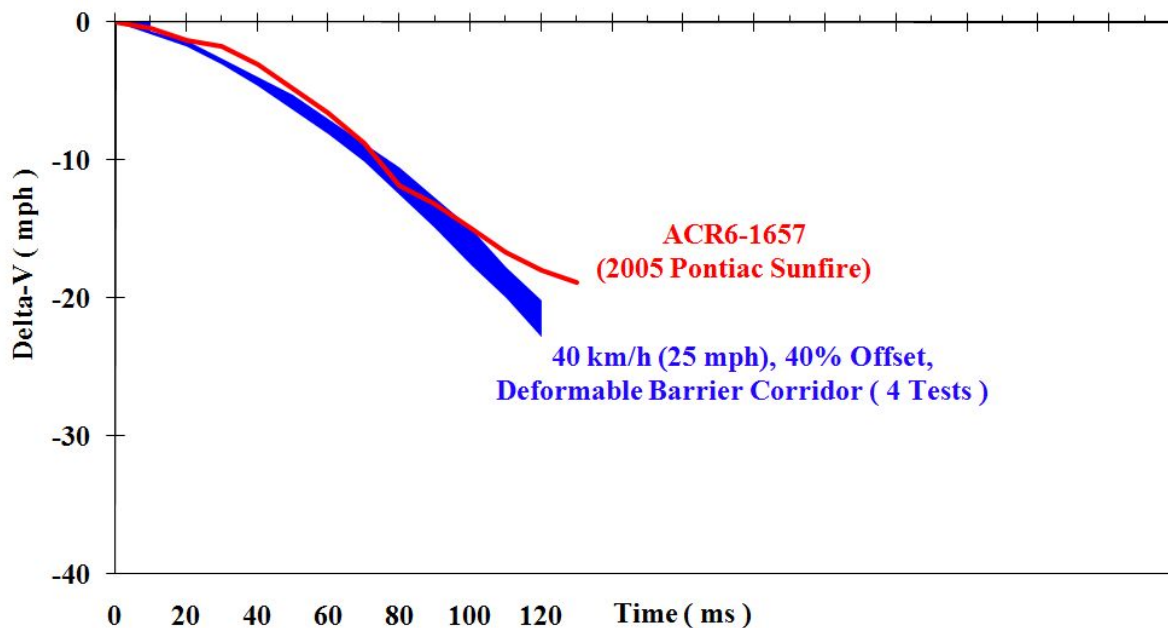
Frontal Offset Deformable Barrier Crash Tests

**Figure 7. Comparison of a real-world crash pulse with
40 km/h offset frontal deformable barrier tests**

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   10

ACR6-1617

A 2000 Pontiac Grand Am four-door sedan was southbound on a four-lane, undivided, urban arterial roadway with a posted speed limit of 50 km/h. The Grand Am was travelling at 61 km/h as it approached a four-leg intersection. A 2000 Saab 900 two-door sedan, originally travelling northbound, had stopped at the intersection and had its left-turn signal activated.   A 2002 Chevrolet Cavalier two-door coupe, coming up behind the Saab, was travelling at 72 km/h.

The Cavalier's driver failed to observe that the Saab was stationary until he was in close proximity to the latter. He braked and steered to the left. The front-right side of the Cavalier sideswiped the Saab's left-rear bumper. The Cavalier continued moving forward, and came into a head-on collision with the southbound Grand Am.

2002 Chevrolet Cavalier   **2000 Pontiac Grand Am**

There was damage across the entire front end of the Cavalier with a maximum crush of 55 cm at bumper level (12FDEW3). There was no occupant compartment intrusion. The vehicle's EDR recorded a maximum delta-V of 48 km/h (30 mph), and an air bag firing time of 15 ms.

The 28-year-old, male driver of the Cavalier was fully-restrained. The load-limiter in the seat belt retractor had activated and the air bag had deployed. The driver sustained a fracture of the left clavicle (AIS 2) as a result of seat belt loading.

ACR6-1657

A 2005 Pontiac Sunfire four-door sedan was southbound at approximately 70 km/h in the curb lane of a four-lane, urban arterial roadway. The posted speed limit was 50 km/h. A 2002 Buick Century four-door sedan was stopped in the curb lane, ahead of the Sunfire.

The Sunfire's 28-year-old, female driver initially failed to observe the stationary vehicle. On realizing that the Cavalier was directly ahead, she braked hard; however, the front of the Sunfire vehicle struck the rear of the Century.

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   11

2005 Pontiac Sunfire   **2002 Buick Century**

The front bumper of the Sunfire underrode the rear of the Century. Damage to the Sunfire extended primarily across the left side and centre of the front end (12FDEW2). There was crush at both the bumper and the radiator support level, with the maximum averaged crush being 30 cm, measured at the left front corner.

The EDR in the Sunfire recorded a maximum delta-V of 31 km/h (19 mph), and an air bag firing time of 30 ms. The Sunfire's driver was fully restrained and sustained no injuries as a result of the collision.

Crash Pulse Characteristics

Due to the large number of real-world collisions in the sample, plotting multiple crash pulses on a single chart in order to examine their overall nature is not feasible. Consequently, Figure 8 shows individual crash pulses at various levels of maximum delta-V, each being somewhat representative of similar crashes within a discrete range of delta-V.

Using this over-simplified chart, we can see that, in general, for the crash pulses in the real-world sample, the greater the maximum delta-V, the greater is the slope of the initial portion of the delta-V time history curve. The data further suggest that the length of the crash pulse varies as a function of the object contacted. When one controls for the object contacted, the length of the crash pulse appears to be independent of the maximum delta-V, i.e. the length of the crash pulse of a vehicle experiencing a hard 40 km/h delta-V crash will be very similar to that for a vehicle experiencing a hard 56 km/h delta-V crash.

This can be seen in Figure 9 for a series of full-frontal rigid barrier tests conducted using Chevrolet Trailblazer sport utility vehicles. In this test series, the Chevrolet Trailblazer showed an identical pulse duration in 40, 48 and 56 km/h rigid barrier crash tests. The tendency for crash pulse duration to be independent of delta-V can be exploited to generate various parameter mappings over the range of collision severities. For example, in a recent study, the effect was used to calculate the expected shoulder force which would be developed as a function of occupant height and weight over the range collision severities to which the driving population were likely to be exposed. In turn, this allowed the likely benefits that would be derived from different levels of load-limiting to be estimated. [15]
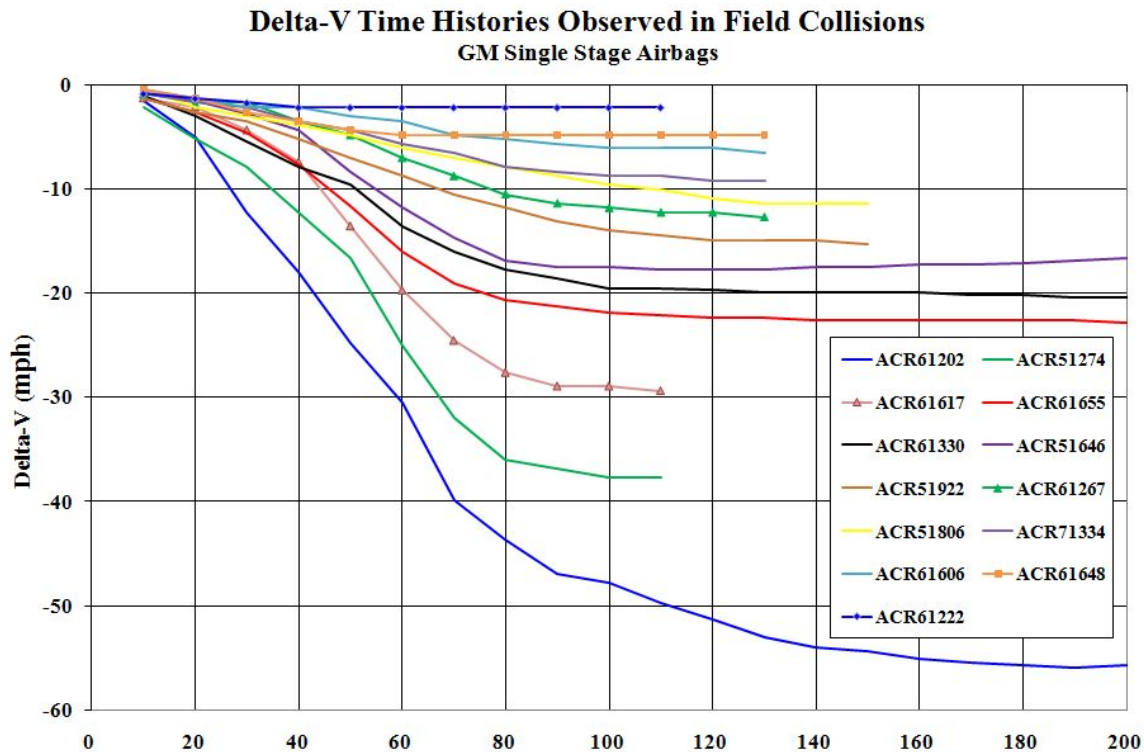
Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   12

Delta-V Time Histories Observed in Field Collisions
GM Single Stage Airbags

Figure 8. Crash Pulse Characteristics

40-56 km/h (25-35 mph) Full Frontal Rigid Barrier Crash Tests
Chevrolet Trailblazer Test Series
Corridor: Staged Collisions @ 48 km/h (30 mph), Maximum Delta-V >= 48
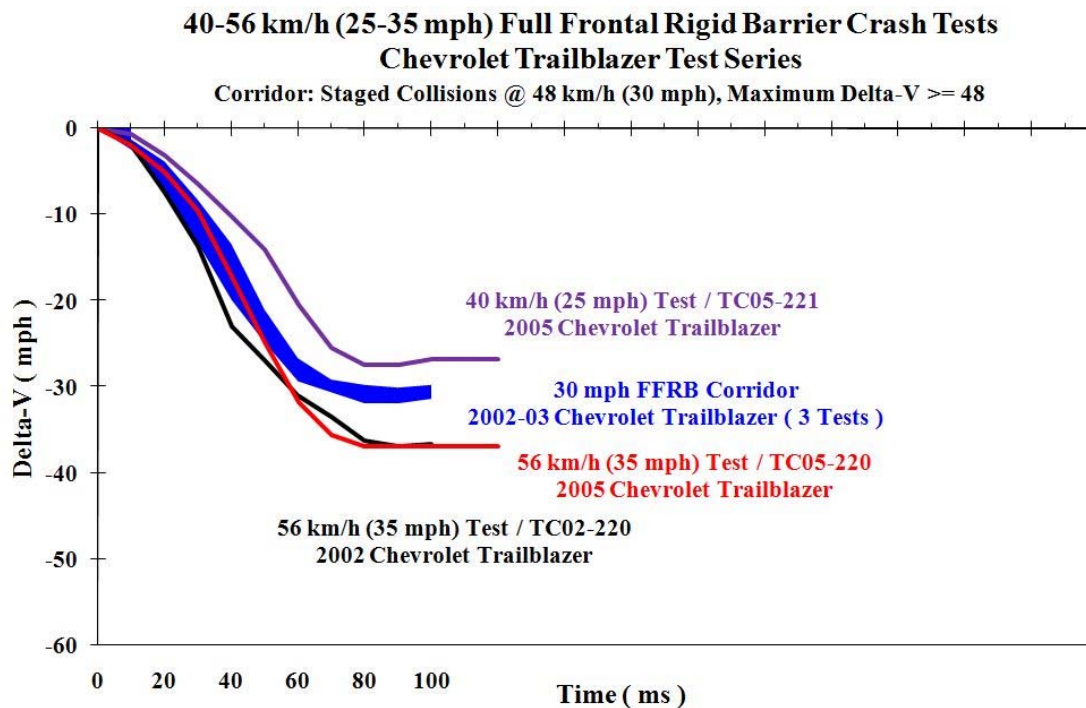

**Figure 9. Crash Pulses for Full Frontal Rigid Barrier Crashes
With 2002, 2003 and 2005 Chevrolet Trailblazers**

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   13

DISCUSSION AND CONCLUSIONS

The information captured by on-board event data recorders provides a valuable adjunct to Canada's programme of in-depth collision investigations. While on an individual basis such data can assist investigators in determining or confirming certain specific aspects of a collision, the aggregate data are extremely useful in furthering our understanding of crashes and, in particular, providing insight into the performance of active safety systems such as air bags.

From the data presented in this paper, we may readily conclude:

(1) Air bag firing times are much shorter in rigid barrier crash tests than in almost all real world collisions suggesting that deployment algorithms are finely tuned for this test configuration.

(2) Air bag firing times in "soft" staged collisions, such as offset-frontal crash tests using deformable barriers, are comparable to those observed in many real-world collisions, confirming the desirability of developing such additional test configurations.

(3) Most real-world collisions are much less severe than the 48 km/h full-frontal rigid barrier crash test, and only a small minority are more severe than this test.

(4) Some real-world crash pulses closely match those seen in staged collisions undertaken both for compliance purposes and for regulatory development.

(5) In general, impacts having low maximum delta-V's produce less steep onsets in the crash pulses. The data further suggest that the length of the crash pulse varies as a function of the object contacted.

(6) Some EDR's do not record the complete crash pulse due to storage limitations. In the event of a "hard" impact, like that with a rigid barrier, 100-120 ms of crash pulse data are generally sufficient to describe the entire event. In longer duration crashes, the rebound phase of the collision, and possibly part of the total delta-V, may not be captured.

(7) There are some timing issues in the data capture process that result in apparent time shifting of the delta-V time history profiles.

(8) For the standard 48 km/h full-frontal rigid barrier crash test, the crash pulses are closely grouped even for a range of different vehicles. The same situation applies to the 40 km/h, 40% offset, frontal crashes with deformable barriers.

(9) The crash pulses associated with the rear underride guard tests were quite variable, but this research programme was conducted using different impact speeds, and guards with different geometry and stiffness characteristics.

ACKNOWLEDGEMENTS AND DISCLAIMER

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   14

REFERENCES

1   Chidester A, Hinch J, Mercer TC and Schultz KS; Recording Automotive Crash Event Data; Proc. International Symposium on Transportation Recorders; Arlington, VA; 1999

2   Crash Data Retrieval; Bosch Diagnostics; http://www.boschdiagnostics.com/testequipment/cdr/Pages/CDRHome.aspx

3   DaSilva MP; Analysis of Event Data Recorder Data for Vehicle Safety Improvement; Report No. DOT HS 810 935; NHTSA; Washington, DC; April, 2008

4   Event Data Recorders; Summary of Findings by the NHTSA EDR Working Group; Final Report; Docket No. NHTSA-1999-5218-9; NHTSA; Washington, DC; August, 2001; http://www.regulations.gov

5   Comeau J-L, German A and Floyd D; Comparison of Crash Pulse Data from Motor Vehicle Event Data Recorders and Laboratory Instrumentation; Proc. CMRSC-XIV; Ottawa, ON; 2004

6   Niehoff P, Gabler HC, Brophy J, Chidester C, Hinch J and Ragland C; Evaluation of Event Data Recorders in Full System Crash Tests; Paper No. 05-0271-O; Proc. 19th. ESV Conf.; 2005

7   Gabler HC, Thor CP and Hinch J; Preliminary Evaluation of Advanced Air Bag Field Performance using Event Data Recorders; Report No. DOT HS 811 01; National Highway Traffic Safety Administration; Washington, DC; August, 2008

8   Dalmotas DJ, German A, and Welbourne ER; Directed Studies: A Focused Approach to Collision Investigation; Proc. CMRSC-IX; Montreal; 1995

9   Dalmotas, D.J., Assessments of Air Bag Performance Based on the 5th Percentile Female Hybrid III Crash Test Dummy, Paper No. 98-S5-O-07, 16th International Technical Conference on the Enhanced Safety of Vehicles, Windsor, Ontario, Canada, 1998

10 European New Car Assessment Programme (Euro NCAP) - The tests explained - Frontal impact; http://www.euroncap.com/tests/frontimpact.aspx

11 Frontal Offset Crashworthiness Evaluation, Offset Barrier Crash Test Protocol (Version XIII); Insurance Institute for Highway Safety; Arlington, VA; May, 2008

12 Boucher D and Davis D; Trailer Underride Protection – A Canadian Perspective; SAE 2000-01-3522; 2000

13 Collision Deformation Classification – SAE J224 MAR80; Society of Automotive Engineers; Warrendale, PA; 1980

14 Federal Motor Vehicle Safety Standards, Occupant Crash Protection, Final Rule; Department of Transportation, National Highway Traffic Safety Administration; Federal Register; 49 CFR Parts 552, 571, 585 and 595; Vol. 65, No. 93; May 12, 2000

15 Mertz HJ and Dalmotas DJ; Effects of Shoulder Belt Limit Forces on Adult Thoracic Protection in Frontal Collisions; Paper 2007-22-0015; 51st Stapp Car Crash Conference, San Diego, California, October 29-31, 2007

Proceedings of the 19th Canadian Multidisciplinary Road Safety Conference,
Saskatoon, Saskatchewan, June 8-10, 2009
Compte-rendu de la 19e Conférence canadienne multidisciplinaire sur la sécurité routière,
Saskatoon, Saskatchewan, 8-10 juin 2009   15