

D.A. Aylor, J.M. Nolan, D.S. Zuby, B.C. Baker
Insurance Institute for Highway Safety, Arlington,
USA

How the 64.4km/h (40mi/h) Frontal Offset Deformable Barrier Crash Test Relates to Real-World Crash Severity

Abstract

This study updates previous IIHS studies comparing estimated delta Vs for crash tested vehicles to the distribution of estimated delta Vs in the National Automotive Sampling System (NASS) Crashworthiness Data System (CDS). The delta V estimates for 232 frontal crash tests at 64.4km/h into a deformable barrier with 40 percent overlap are compared with estimates from frontal offset crashes in the 1997-2004 NASS database. All delta V estimates were based on SMASH, the delta V estimating program used by NASS since 1997. Results indicated that for all vehicles tested by IIHS, SMASH delta Vs were, on average, 32 percent lower than impact speeds and about 28 percent lower than the expected delta V. Almost 80 percent of all real-world frontal crashes resulting in AIS 3+ injuries and just over 60 percent of all fatal crashes occur at or below the average estimated delta V calculated for crash tested vehicles.

Introduction

Since 1995 IIHS has conducted frontal offset deformable barrier crashworthiness tests as part of a consumer information program. In the offset test, 40 percent of the vehicle's width strikes a deformable barrier at 64.4km/h [1]. The effectiveness of consumer testing depends on the test configuration and speed being relevant to real crash situations and on the test producing a range of test results. Frontal offset crashes make up a significant number of real-world crashes that result in serious injuries to the occupants [2], and the 64.4km/h-test speed initially produced a range of test results [3]. Previous studies showed that this test speed produced a crash severity below which a majority of real-world crashes involving serious injury occurred [4, 5]; thus vehicle changes made in response to these consumer ratings could be

expected to reduce injury risk in similar real crashes. The present study updates the previous studies relating real-world severity with the severity of vehicle crash tests by providing results from an additional 175 crash tests of 1998-2005 model year cars, minivans, pickups, and SUVs and using more recent NASS data [6].

Real-World Crash Severity

Crash severity is frequently gauged by delta V, which is the velocity change that occurs during the crash impact and which can be related to crash forces if the time over which the delta V occurs is assumed to be similarly small for all crashes. Delta V is calculated using the principles of conservation of energy and momentum plus an estimate of the energy absorbed in crushing the vehicle structure, which is based on measurements of the crashed vehicle and estimates of its structural stiffness. Because it only accounts for velocity change associated with vehicle crushing and does not include structural restitution or post-impact kinematics, delta V generally is not an estimate of the speed just prior to impact. Despite being only a rough estimate of the accelerations and forces involved in a crash, delta V is a useful measure because it is available for many crashes in NASS. The same measure can be applied for vehicles subjected to crash tests under known conditions.

The delta V for frontal offset crashes against a fixed barrier, like the tests that are the subject of this analysis, will be lower than the impact speed because the vehicle's center of mass does not stop at maximum crush. However, the forward velocity due to vehicle rotation and vehicle rebound is relatively small. The 1998 study used high-speed film to analyze the rotation of vehicles in the offset test and found that the energy associated with rotation accounted for 2 to 3km/h [2].

Methods

This analysis includes delta V estimates for 232 frontal offset crash tests, which include 134 passenger cars, 64 SUV, 22 minivans, and 12 pickup trucks. Each tested vehicle's front crush was measured according to the protocol established for crash reconstructions using the SMASH algorithm that has been used in NASS since 1997. The vehicle stiffness values for each reconstruction were assigned according to the same size/stiffness

categories used by NASS investigators. The crash test delta Vs were compared with frontal offset crashes in the 1997-2004 NASS CDS database. Crashes were selected based on the Collision Deformation Classification, which includes principal direction of force, impact location, and amount of direct engagement. All single- and two-vehicle towaway crashes coded as frontal (19,648 cases), with one-third to two-thirds direct damage to the front-end and 11 to 1 o'clock principal direction of force (9,001 cases), were initially included, but comparable delta V estimates were only available for about half (4,487) of these cases.

Results

The SMASH delta Vs were not only lower than the 64.4km/h crash test speed but also lower than the test vehicles' expected delta Vs when an estimate

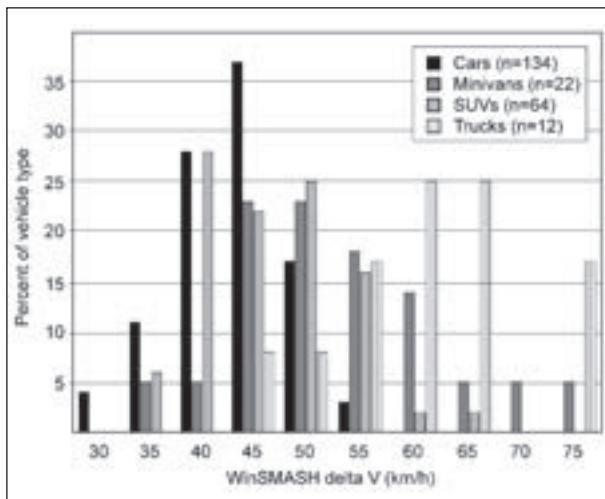


Figure 1: Histogram of estimated delta Vs for IIHS tests

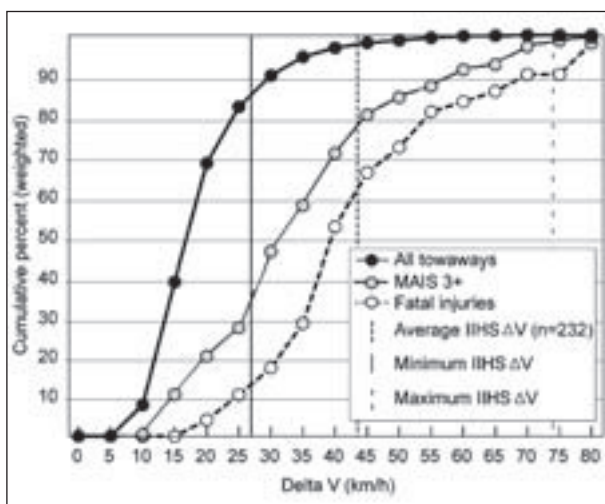


Figure 2: Cumulative distribution of delta Vs by injury level

of vehicle rotation is taken into account. The average SMASH delta Vs was 36 percent lower than the impact speed for cars, 21 percent lower for minivans, 31 percent lower for SUVs, and 9 percent lower for pickup trucks. The average SMASH delta V for all vehicles was 44km/h, or 32 percent lower than the impact speed. Taking into account the velocity associated with vehicle rotation found in the previous study, the SMASH delta Vs are approximately 28 percent lower than the actual delta Vs. Not only did SMASH underestimate delta V but there was considerable variation in the estimates for these 232 vehicles, all of which were subjected to the same crash test. Figure 1 shows the distribution of SMASH delta V estimates by vehicle type.

Figure 2 compares the range and average of SMASH delta V estimates for crash tested vehicles with the delta V distribution of crashes in NASS. Just under 80 percent of MAIS 3+ injuries and slightly more than 60 percent of fatalities occur at or below a delta V of 44km/h. The wide range of delta V estimates for the tested vehicles (27 to 74km/h), however, indicates considerable uncertainty as to which portion of the NASS crash distribution is most similar to the laboratory crash test.

Discussion

The underestimate and wide variation of the crash test delta V resulting from SMASH calculations largely are due to the use of inappropriate vehicle stiffness estimates contained in the generalized stiffness categories. For instance, the 1996 Toyota Previa and 1996 Mazda MPV had similar test weights and are assigned the same stiffness category in SMASH. The SMASH estimated delta V for the Previa was only 47km/h while the estimated delta V for the MPV was 72km/h. These results indicate that the Previa is much stiffer than the MPV and should not have the same categorical stiffness. Furthermore, the stiffness value to which both vehicles are assigned is not particularly representative of the actual stiffness of either vehicle. Previous studies showed that the delta V estimation would be more accurate if the vehicle-specific stiffness coefficients were used [3], but NASS delta V estimates continue to be based on the generalized stiffness categories [7]. This practice leads to considerable uncertainty in relating laboratory crash tests to the real-world counterparts in NASS.

The large number of crash tested vehicles for which SMASH delta Vs were made in this analysis allows a good estimate of the general severity of the test. Almost 80 percent of serious injuries and more than 60 percent of fatalities in real-world offset crashes occur at or below the average delta V estimated for the IIHS frontal offset test, reconfirming that the test is similar to the kinds of real crashes that cause serious injuries and sometimes cause occupant deaths. Manufacturers have responded to IIHS tests with major improvements to vehicle structure, so that the range of performance has narrowed. Most vehicles now perform very well and research shows that vehicles with better ratings provide better occupant protection in the real crashes [8].

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