C17 Analysis of an Alleged Premature Air Bag Deployment—Achieving Firm Conclusions With Limited Vehicle Data

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The goals of this presentation are to explain the detection and calculation methodology of a single point crash sensor, and then explain a methodology to prove an improper response of such a single point air bag crash sensor by using mechanical component analysis. This mechanical component analysis confirmed, with a reasonable degree of engineering certainty that the single point sensor responded to a below-deploymentthreshold impact velocity change.

Theory of the Analysis: Analysis of crash events in contemporary vehicles considers both magnitude and principal direction of force (PDOF) as shown in Figure 1. When those crash contemporary air bag deployment controllers evaluate events, that evaluation is usually accomplished by single point crash sensing *transducers*, which provide a ratiometric electrical voltage output representing the physical acceleration magnitude of a crash event. For frontal air bag deployment systems (or subsystems), the crash detecting sensors are aligned to detect force inputs in the -X axis direction, as shown in Figure 1. Thus, any off-axis crash force input must be geometrically corrected in order to properly characterize the crash sensor response. Figure 1 shows one such correction.

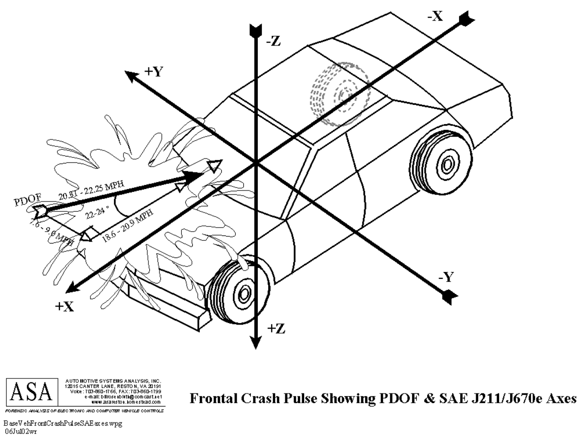

Figure 1

The transducer used in contemporary single point crash sensors is a solid-state accelerometer. An accelerometer is a transducer, which translates an input mechanical quantity (acceleration) into an output electrical quantity (volts). More precisely, the transducer responds to a change in velocity produced by a vector component of the force exerted on vehicle (acceleration, a =)V_{-X}/t), and produces a differential electrical signal (voltage difference from a quiescent voltage value) proportional to that acceleration (vector component).

The sensitivity of accelerometers is usually expressed in terms of units of standard electrical output (volts) per units of a standard acceleration (gravity, "Gs"). In operation, the accelerometer output (volts/G) is converted into a digital numeric value by an Analog/Digital (A/D) converter, usually incorporated internally within a microcontroller within the single point crash sensing assembly (SRS ECU). In order to evaluate the crash magnitude, and, thus, make a deploy/no-deploy decision, a time series of those converted digital values, saved in digital memory, are filtered, integrated and evaluated by the control program for the microcontroller to calculate a Delta V and oscillation profile of that crash event. Those calculated Delta V and oscillation profiles (short term variations in acceleration values) are then compared to desired deployment thresholds or data tables, so that a valid deploy/no-deploy decision can be made. Figure 2 shows an amplified schematic of that process.

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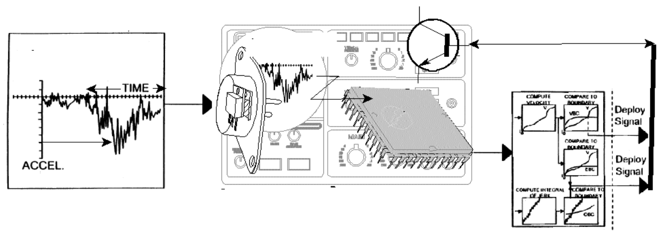

Figure 2

In the subject case, the air bags in a 1994 Volvo 940 were deployed by a single point sensing controller as described above, and caused injury to the driver. However, the vehicle physical damage did not appear to be consistent with the established deployment criteria. The manufacturer's expert opined that, because the air bags were deployed, the crash magnitude had to be above the proper threshold, thus, assuming that the single point sensor was "infallible," and that there was certainly no defect in the system. Because of this variance in observed versus assumed data, I was asked to investigate this matter.

Notwithstanding assumptions of infallibility, there are conditions that can cause a single point sensing controller to misfire its associated air bags. Examples of these include:

A. The faulty use of A/D range shifting wherein, for certain program branches, an acceleration voltage translation done at a 10 bit resolution is actually evaluated at an 8 bit resolution, and the result of a faulty translation is that the acceleration digital value evaluated by the microcontroller algorithm is actually 2x or 4x the correct value.

B. The accelerometer transducer can have various sensitivity modes (volts/G) dependent on installation circuitry and on potential electrical artifacts (short circuits - open circuits) on the printed circuit board in the SRS ECU. Such sensitivity variations can range from null (zero output) to 2x the expected sensitivity.

With such potential conditions, one cannot simply assume that the crash sensor is always infallible in its judgement of crash magnitude.

In the subject accident, the Subject Vehicle (SV), a 1994 Volvo 940, was entering a parking lot when it contacted the rear end of another vehicle (1990 Toyota Wagon). The air bags in the 1994 Volvo deployed and the driver was injured. After the accident the Toyota was driven away, and the Volvo was towed. The driver of the Volvo estimated that she was going 8-10 mph maximum.

A photographic observation of the SV revealed no significantdiscernable impact damage. The driver of the 1990 Toyota stated that there was no structural damage to her vehicle, and this was confirmed by Toyota mechanics. Neither of the vehicles was available for inspection.

The only evidentiary materials consisted of a Volvo investigation report, done at the time of the accident, which confirmed the following artifacts:

A. Both left front (LF) and right front (RF) air bags deployed, and the seat belt pretensioners deployed (all fired by a single firing criteria). There were SRS fault codes (DTCs) indicative of an air bag deployment.

B. The knee bolster cover panel was kicked off as a result of the accident.

C. The impact was frontal, distributed across the front bumper only.

D. There was scuffing of the front bumper, and it was separated from its right side guide.

E. The two front collision isolators stroked 24 mm each (both LF and RF).

F. No structural damage to the Volvo was noted.

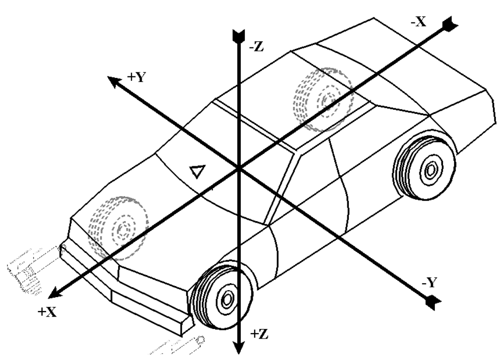

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Figure 3

Given this minimum fact set, and the unavailability of the subject crash sensor for purposes of reading its EEPROM crash record, the author proceeded to initiate an analysis of the available data regarding forces in the subject collision. The only collision-force-related artifact was the collision isolator data. Collision isolators serve to insulate the vehicle from minor damage by allowing (restorable) bumper stroking, up to a hard damage limit. They are usually positioned in the front and rear bumpers as shown in Figure 3.

Stroking definitions and collision isolator detail are shown in Figure 4.

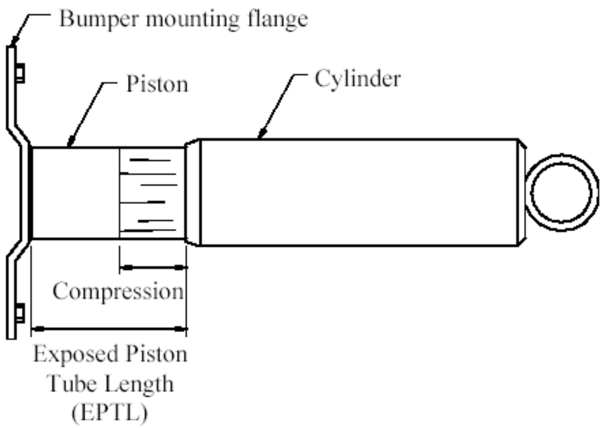

Figure 4

In this case, in order to evaluate the subject Volvo isolator data, the author contracted for a collision isolator analysis with David King, MacInnis Engineering, Lake Forrest, CA. He proceeded to use an instrumented moving barrier with exemplar Volvo isolators in order to characterize their response with respect to the data point noted in the Volvo report (24 mm stroke).

The replacement isolators were dynamically tested following the protocol set out in an SAE 1999-01-0096, "Comparison Testing of Bumper Isolators." In that protocol, a single isolator is mounted to the front of a moving barrier that was rolled into an instrumented fixed barrier at varying speeds. For each test, the isolator compression, moving barrier speed and the time-varying nature of the collision force were measured. The test data were then scaled to correct for the mass difference between the moving barrier (722 kg) and the 1994 Volvo 940 published mass (1454 kg plus 66 kg 50th percentile female). Thirty-five tests were done with the right front isolator and eighteen tests were done with the left front isolator.

The results of the exemplar collision isolator analysis show that the speed change associated with 24 mm of compression is approximately 4 mph. That is, if a 1994 Volvo 940 was rolled into a fixed barrier such that the average front bumper isolator compression was 24 mm (both isolators), the vehicle would have sustained a 4 mph speed change into the barrier. A graphical summary of that analysis data is shown in Figure 5.

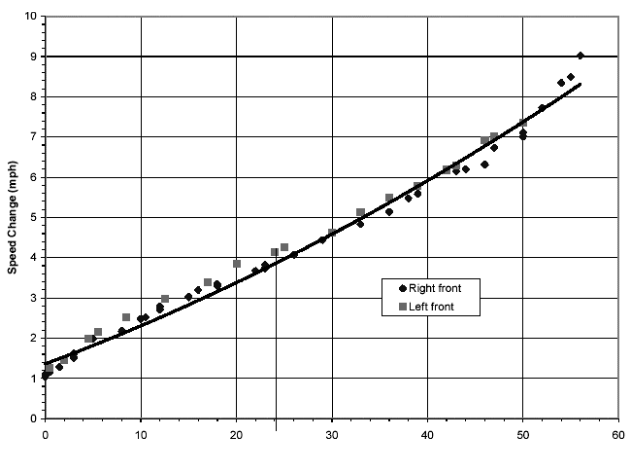

Figure 8. 1994 Volvo 940 front isolator test results. The vertical line crosses the X-axis at 24 mm compression. This represents a speed change of 4 mph.

Figure 5

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That velocity change characterization is also known as a barrier equivalent velocity (BEV). However, in a collision between two reasonably similar vehicles (which do not behave like barriers, and are considerably "softer" than barriers), the BEV tends to approximate ½ the closing velocity between the two vehicles. This helps to explain the witness reports that the Volvo was traveling at approximately 8-10 mph when it hit the Toyota, and, thus, demonstrated probable witness veracity.

The 1994 Volvo fixed barrier speed change thresholds (BEV) were specified to be:

A. Less than 8 mph ==> must-not-fire

B. Greater then 12 mph ==> must-fire

Thus, using a scientific method to evaluate the only data available to us (and that being defendants' own investigation data), it was confirmed with near certainty that the Volvo air bag controller appeared to have fired its air bags at a BEV well below its specified must-not-fire threshold. The case settled to the satisfaction of the parties.

Air Bag Crash Analysis, Air Bag Premature Deploy, Collision Isolator Analysis