

Comparison of Heavy Truck Engine Control Unit Hard Stop Data with Higher-Resolution On-Vehicle Data

Fawzi P. Bayan, Anthony D. Cornetto III, Ashley (Al) Dunn, C. Brian Tanner, Eric S. Sauer, Brian Bogges, Douglas R. Morr, Rickey L. Stansifer and Scott A. Noll
SEA, Ltd.

Grant J. Heydinger and Dennis A. Guenther
The Ohio State University

Copyright © 2009 SAE International

ABSTRACT

Engine control units (ECUs) on heavy trucks have been capable of storing “last stop” or “hard stop” data for some years. These data provide useful information to accident reconstruction personnel. In past studies, these data have been analyzed and compared to higher-resolution on-vehicle data for several heavy trucks and several makes of passenger cars. Previous published studies have been quite helpful in understanding the limitations and/or anomalies associated with these data. This study was designed and executed to add to the technical understanding of heavy truck event data recorders (EDR), specifically data associated with a modern Cummins power plant ECU. Emergency “full-treadle” stops were performed at many combinations of load-speed-surface coefficient conditions. In addition, brake-in-curve tests were performed on wet Jennite for various conditions of disablement of the braking system. This study shows how the ECU data compares to higher-resolution data acquired by independent data acquisition computers and transducers. The goal of this study was to help accident reconstruction professionals better understand engine ECU “hard stop” data currently available on most commercial vehicles.

INTRODUCTION

Technical research on ECU data has been relatively limited. Some of the most notable work (as discussed in

more detail below) was published by Roland Ruhl et. al [1] for the Mack V-MAC III System, Timothy Reust [2] for the Detroit Diesel DDEC III or DDEC IV systems, Sebastian van Nooten and James Hrycay [3], Timothy Reust and James Morgan [4] for the Detroit Diesel DDEC IV system, and Kerry Drew et al. for the Caterpillar Advanced Digital Engine Management III Controller.

The authors of this research paper wanted to add to the past studies while evaluating an additional system, namely the Cummins ECU Powerspec sudden deceleration system. This work seeks to analyze the accuracy and limitations of the pre-braking, braking, and post-braking recorded data. In addition to straight-line sudden stops in dry conditions, testing was also performed in curves on a wet surface with various levels of ABS disablement. The ability of the ECU to predict actual speed in these conditions was studied.

RESEARCH

TEST VEHICLE – The test vehicle used in this research consisted of a 2006 International 9400i 6x4 conventional tractor, pulling a 2000 Trailmobile 2-axle 48-foot long flatbed semi-trailer. The vehicle is shown in Figure 1 during a test at the GCW load condition. Vehicle details are located in tables in the Appendix of this paper. The vehicle was loaded using calibrated weights at the Transportation Research Center (TRC), which were placed on the truck to achieve axle weights that would

span those seen in normal use. The three loading conditions chosen include gross combined weight of 80,000 pounds (GCW), half-payload, and zero-payload (LLCW) conditions. As-tested axle weights are listed in tables in the Appendix. The service brakes on the truck had been properly maintained and were in proper working order at the time of this test. Care was taken to obtain a tractor and semi-trailer whose brakes were suitably worn in, so burnish state would not be an issue. Brake stroke measurements were taken at the beginning and end of each test day.



Figure 1 - Photograph of tractor and semi-trailer at GCW during a braking maneuver.

TEST FACILITY – The test facility for straight-ahead stopping tests was the concrete Skid Pad at the transportation Research Center (TRC), located in East Liberty, Ohio. The concrete skid pad is heavily used in vehicle straight-line braking tests. The section of the Skid Pad that was used in this testing was measured to have nominal ASTM peak and slide traction levels of 0.93 and 0.82, respectively. The braking-in-curve stopping tests were performed on the 500-foot radius curved wet Jennite surface at TRC. TRC's wet Jennite is an asphalt test pad coated with a Jennite sealant to achieve lower tire-surface coefficients of friction. The nominal ASTM traction levels were 0.15 and 0.4 for peak and slide, respectively.

TEST PROCEDURE – The truck straight-line brake testing was performed in general adherence to SAE J1626, and those procedures accepted by the National Highway Traffic Safety Administration (NHTSA) when testing trucks for FMVSS No. 121 compliance. Stopping distances were recorded using a Labeco mechanical fifth wheel that recorded initial braking speed and stopping distance. Speed signals were digitally recorded from an OXTS RT-3000 GPS-based inertial measurement unit mounted near the tractor's unloaded C.G., and by a Datron optical fifth wheel mounted under the semi-trailer, near the midway point between the kingpin and tandem

axles. The vehicle was accelerated to near the initial test speed, and then the brake pedal was fully applied while simultaneously de-clutching. Initial braking temperatures were monitored and initial braking temperature was controlled to remain less than 300 °F (149 °C). Brake applications were full-treadle, and the tractor and semi-trailer ABS prevented wheel lock on the controlled brake positions. For each load condition, a set of stops was recorded at the baseline condition (all brakes functioning properly). On the wet Jennite, the stopping tests were performed along a 500-foot radius curve. In the wet tests, the ABS was selectively disabled on the brakes of the tractor, the semi-trailer or both.

RECORDED DATA – In addition to initial braking speed and integrated stopping distance being registered by the Labeco 625 system, the following data were digitally collected and stored:

1. Tractor position (x, y, and z) near the C.G.
2. Longitudinal, lateral, and vertical accelerations (A_x , A_y , and A_z) near the C.G. of tractor and the semi-trailer
3. Tractor roll, yaw, and pitch angles and rates
4. Semi-trailer roll, yaw, and pitch rates
5. Tractor speed in the longitudinal, lateral, and vertical directions (V_x , V_y , and V_z) near the C.G.
6. Semi-trailer lateral speed (V_y) and composite (resultant) speed
7. Individual wheel speeds on the tractor and semi-trailer
8. Brake pressures on the tractor steer axle, the left brake position on the tractor drive axles and semi-trailer axles (positions 1, 2, 3, 5, and 7)
9. Tractor primary and secondary control pressures
10. Semi-trailer control pressure
11. Tractor drive axle brake stroke (1 brake)

Tractor inertial parameters (velocities, accelerations, rates of rotation, etc.) were measured via a RT-3000 GPS-based system. The RT-3000 was mounted directly to the frame of the tractor, on the centerline, as close as could be to the estimated position of the tractor's unloaded C.G. Semi-trailer inertial parameters (accelerations and rates) were measured via a Crossbow 6-axis IMU that was mounted half way between the kingpin and rear tandems, on the lateral centerline of the semi-trailer. Semi-trailer speeds were measured at the same location using a Datron two-axis optical fifth wheel. Brake pressures were measured using calibrated pressure gauges. Wheel speeds on all ten-axle ends were measured via DC tachometers and filtered with a 10 Hz, zero-phase digital low pass filter that emulates a 12-pole Butterworth. Finally, ECU sudden deceleration data recorded by the vehicle was also downloaded. The ECU data was not downloaded for each run. Several downloads were unusable due to experimental problems. Accordingly, a limited number of

usable ECU downloads were obtained and are presented in this paper.

ECU DATA

Review of the testing that included ECU data yielded two groups of test results for the purpose of analysis. Group A (see Table A) tests were performed in a straight line, on a dry surface with ABS functioning on both the tractor and the semi-trailer. These tests were performed at all three loading conditions (GCW, half-payload and LLCW). Tests for the GCW and LLCW loading conditions were performed at approximately 60 mph. For the half-payload loading condition, tests were conducted at test speeds of approximately 30 and 60 mph.

Group B (see Table B) includes all tests performed along a curved path on the wet Jennite surface. The tests were conducted at approximately 30 mph with various braking conditions: ABS enabled, ABS disabled on the tractor only and ABS disabled on the semi-trailer only. All the tests in Group B were performed for a half-payload condition.

Table A: Group A Tests

Run	Speed (mph)	Load	Surface	ABS
14	60	LLCW	Dry concrete	All enabled
54	60	GCW	Dry concrete	All enabled
135	60	Half-Payload	Dry concrete	All enabled
136	30	Half-Payload	Dry concrete	All enabled

Table B: Group B Tests

Run	Speed (mph)	Load	Surface	ABS
115	30	Half-Payload	Wet Jennite	Tractor disabled
116	30	Half-Payload	Wet Jennite	All enabled
117	30	Half-Payload	Wet Jennite	All enabled
123	30	Half-Payload	Wet Jennite	All disabled

Plots for Group A are shown in Figures 2 through 5. The plots show the tractor speed from the RT-3000, the semi-trailer speed from the Datron, a calculated wheel speed obtained by averaging the drive axle data, and the speed recorded by the Cummins ECU. The analysis and discussion focuses on the accuracy of the ECU speed

relative to the RT-3000 speed and its level of correlation with the instrumentation. The wheel speed data from the tractor drive axles was used to align the timeline for the ECU data with the timeline for the RT-3000 data and Datron data.

The difference after initiation of braking between the calculated average wheel speed and the ECU reported speed (output from the transmission shaft) as seen on all Figures is the result of effects from the differentials during wheel slip.

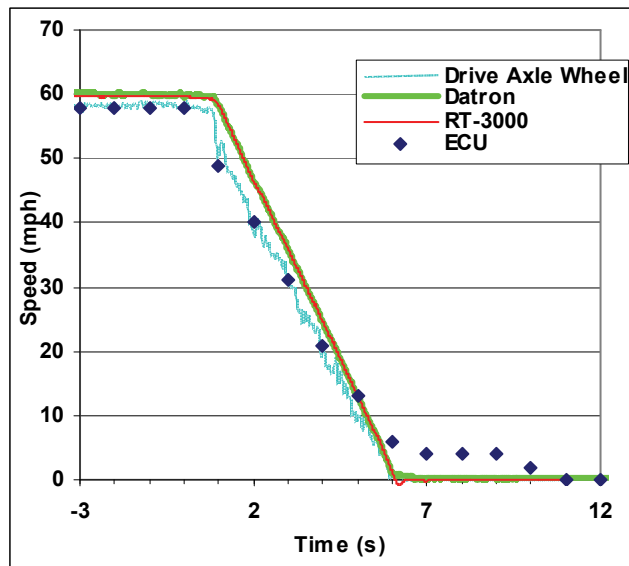


Figure 2: Run 14, 60 mph, LLCW, Dry, ABS enabled.

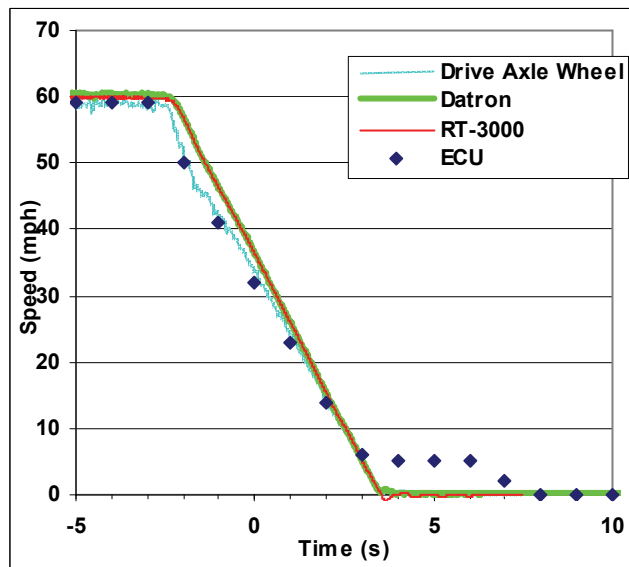


Figure 3: Run 54, 60 mph, GCW, Dry, ABS enabled.