

Method to Determine Vehicle Speed During ABS Brake Events Using Heavy Vehicle Event Data Recorder Speed

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ABSTRACT

Many heavy vehicles have an event data recorder (EDR) that can record pre-event and post-event information. It has been previously reported by researchers that the EDR speed is under-reported during hard braking. Reust (2004) and Reust and Morgan (2006). Well documented tests were conducted with instrumented vehicles to measure time, speed and distance. The vehicles used for this study were equipped with engines manufactured by the Detroit Diesel Corporation. The tests also include measurement of individual wheel speeds and corresponding wheel slip. The authors offer a method to better determine true vehicle speed of a heavy vehicle with air brakes during ABS braking events by using specific speed data from the EDR. The results show that the trend of the EDR-reported speed can be used to determine a precise time of when brake initiation first began. The results of the vehicle speed and brake initiation can be used to calculate travel distance during the brake event.

INTRODUCTION

The vehicles used for this study were equipped with engines manufactured by the Detroit Diesel Corporation. These modern diesel engines incorporate an event data recorder feature with the electronic control module (ECM). The ECM can record pre-event and post-event speeds at one-second intervals, generally 60 seconds preceding the event and 15 seconds after the event. The recorded speed from the ECM is in units of miles per hour with 0.5 mile per hour increments. Other information recorded by the ECM includes engine RPM, throttle percent, brake, clutch, engine load, cruise control, time of day, date and odometer reading. The recorded

“Hard Brake” event can be triggered by brake application or an impact based on a threshold programmed speed change, commonly a setting of 7 miles per hour per second. This information can be downloaded from the Detroit Diesel Series 60 engines built after January 1, 1998. This information may be available on older vehicles with a ProDriver add-on feature or older engines that have been upgraded with a Detroit Diesel Electronic Control series four (DDEC IV).

After an accident event, the downloaded data from the ECM can be used to assist with the accident reconstruction analysis. The data can make a significant contribution to the reconstruction and in many cases will provide information that traditional methods cannot. The data will expand the analysis of time, distance and speed. This paper addresses how the speed downloaded from the ECM is affected by the operation of the ABS brake system and how to determine a more accurate vehicle speed during the braking phase. The paper also addresses how the ECM data can be used to evaluate brake initiation time and vehicle travel distance.

The brake signal reported by the ECM in one-second time intervals does not provide a precise time of when the brake is first applied. This paper provides a method to determine a precise time of when the brake is first applied.

During an accident reconstruction evaluation, it is often useful to determine the speed of the vehicle just before brake application, the speed at impact, the braking distance and the braking time. The physical evidence and the trend of the speed from the ECM can be used to evaluate when the

collision occurred and then narrowed down to occurring between two specific data points of the ECM speed data. When the brakes are applied leading into a collision, the speed recorded by the ECM is typically underreported due to wheel slip. This paper provides a method to determine an accurate speed of the vehicle for each of the ECM speed data points during braking. Combining the methods of determining when the brakes are first applied and determining an accurate speed of the vehicle during braking can then be used to calculate an accurate range of braking time and braking distance.

VEHICLES

Three different tractor and trailer sets were used for the testing:

2004 Freightliner Columbia 3-axle tractor with a sleeper unit. The engine was a Detroit Diesel Series 60 with a DDEC IV (4). All wheel positions had S-cam brakes with a 4S-4M WABCO ABS system. The semi-trailer was a 2001 Wabash flatbed. All wheel positions had S-cam brakes with a 2S-2M WABCO ABS system. The weight of the tractor was approximately 19,400 pounds (8,818 kg). The combined weight of the tractor and empty trailer was approximately 34,000 pounds (15,455 kg). The combined weight of the tractor and loaded trailer was approximately 80,400 pounds (36,545 kg). The tests series using this combination were labeled as “UD”, “UW”, “LD”, and “LW”.

2007 Freightliner 3-axle day cab tractor. The engine was a Detroit Diesel Series 60 with a DDEC V (5). The ABS system on the tractor was a WABCO 4S-4M. The trailer was a 1999 Utility 2-axle, 48 foot flatbed with a 2S-1M WABCO ABS system. The combined weight of the tractor and empty trailer was approximately 39,180 pounds (17,809 kg). The tests series using this combination was labeled as “LV”.

2008 Western Star 3-axle model 4900SA tractor. The engine was a Detroit Diesel Series 60 with a DDEC VI (6). The ABS system on the tractor was a WABCO 4S-4M. The trailer was a 2007 Landoll Hauloll 3-axle flatbed with an ABS system. The combined weight of the tractor and empty trailer was approximately 56,920 pounds (25,873 kg). The tests series using this combination was labeled as “WS”.

INSTRUMENTATION

Vehicle speed and travel distance were measured using a Racelogic VBOX III GPS system. The unit also has integrated data acquisition capability and the ability to record live CAN data. The Racelogic IMU (inertial measurement unit) was used to record x, y and z acceleration during the tests. The VBOX system has a stated accuracy of 0.1 km/h averaged over four samples and has a latency of 12.5 milliseconds. Brake pedal application was recorded by

placing a tape switch on the surface of the brake pedal. Throttle sensor position was recorded by placing wire taps on the leads of the vehicle's throttle position sensor. Air pressure at the brake chambers were measured by installing pressure transducers in the air lines at the chamber. Pushrod travel was measured using string potentiometers. All of these data channels were recorded by the VBOX system.

TEST PROCEDURE

A series of well-documented heavy truck (air brake) braking tests were conducted in different configurations including wet surface, dry surface, loaded trailer, empty trailer and bobtail (tractor without a trailer). The test speeds ranged between 30 and 60 mph (48 to 96 km/h). For each test the vehicle was accelerated up to the target speed and then the brakes were applied in a rapid and hard manner to simulate a panic type stop. The instrumentation signals were recorded by the data acquisition system. The ECM-reported speed and other engine parameters were recorded as a snapshot through the vehicles' data link connector using a manual snapshot feature of the Detroit Diesel Diagnostic Link program (Detroit Diesel Corporation, Detroit, MI) or using the VBOX CAN feature. After each test the “Hard Brake” event was downloaded from the ECM using the DDEC Reports software (Detroit Diesel Corporation, Detroit, MI).

Each test produced three data sets: the instrumented data, the ECM snapshot data or CAN data and the Hard Brake data. The VBOX III system provided 100 samples per second. The Detroit Diesel Diagnostic Link snapshot feature provided 10 samples per second. The Hard Brake data provided one sample per second.

DATA REDUCTION

The data sets were synchronized in two different ways. When the 10 Hz ECM snapshot data was available, its throttle readings were synchronized with the VBOX throttle tapped data and then the other data such as the speeds were overlaid since they were synchronized by the initial procedure. The CAN data, when available, provided individual wheel speeds and did not need to be synchronized since it was recorded simultaneously with the VBOX speed. After the initial synchronization, the Hard Brake speed data downloaded from the ECM was manually matched to the ECM snapshot speed or CAN speed data. During the data analysis the VBOX speed was used as the actual speed of the vehicle. An example of a synchronized speed graph is shown in (Figure 1). The time data on the graph is related to the running time of the VBOX.

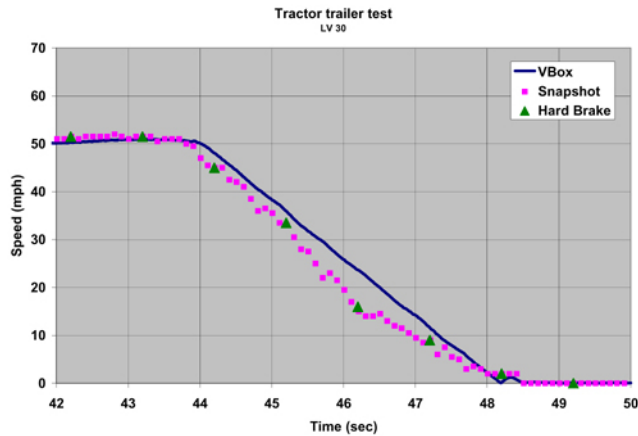


Figure 1. Synchronized speed data

A segment of the speed data from each of the Hard Brake downloads was labeled for further analysis. Label B zero or “B-0” was given to the point where the ECM brake signal first showed as active. The speed sample just before “B-0” was labeled as “B-1”. The samples after “B-0” were labeled in order “B+1” and “B+2”. In the graph shown below, the tape switch registered the brake application at time 33.90 seconds and the Hard Brake event registered the brake signal at time 34.75 (a difference of 0.85 seconds). (Figure 2)

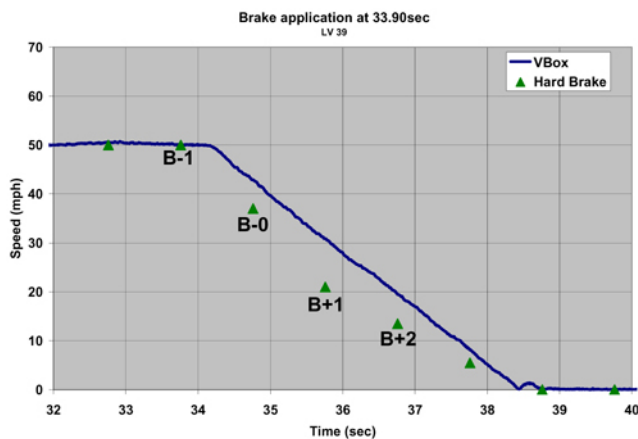


Figure 2. “B-1”, “B-0”, “B+1”, “B+2” points

For each synchronized test, the brake initiation data set was evaluated by looking at the time duration between when the data acquisition system with the tape switch first registered the brake signal and when point “B-0” on the Hard Brake data was reported. The speed decrease was calculated between Hard Brake points “B-1” and “B-0” (ECM speed just before ECM brake signal to ECM speed at first ECM brake signal). Referring again to (Figure 2) the tape switch registered the brake application at time 33.90 seconds and the Hard Brake event registered the brake signal at time 34.75 (a difference of 0.85 seconds). The speed at “B-1” is 50 mph and the speed at “B-0” is 37 mph (a difference of 13 mph).

The data from the tests with the CAN speed data were used to evaluate the amount of wheel slip of the drive wheels during the braking phase. This test was conducted on a dry surface with a tractor and trailer. Speed reported to the ECM is directly related to the rotation of the drive shaft which is connected to the drive-wheels and may differ from the actual speed of the vehicle. (Figure 3)

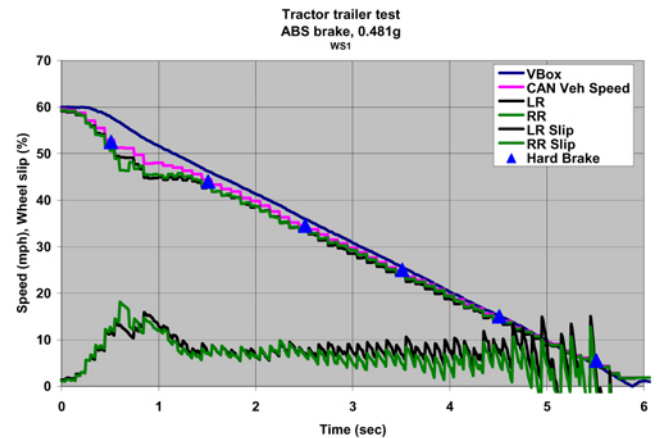


Figure 3. Showing wheel slip during braking on a dry surface

RESULTS

The results of 50 brake tests were combined to form the “Brake to B-0” graph. This graph is used to determine the time duration between when the brake is first applied up to when ECM first records the active brake signal (first ECM brake signal is labeled “B-0”). This graph was created by using the time duration from when the data acquisition system first registered the brake application up to point “B-0” on the Hard Brake. The speed decrease was calculated between Hard Brake points “B-1” and “B-0” (ECM speed just before brake signal to ECM speed at first brake signal). The speed at “B-1” is used because it occurs prior to any braking. The speed when the data acquisition system first registers the brake application also occurs prior to any measurable deceleration. Prior research has shown the accuracy of the ECM speed as ± 1.6 km/h (± 1 mph) during normal operation without wheel slip, Reust (2004). The equation for the trend line is $Y = 0.0549X + 0.149$. The “Y” intercept value of the graph indicates that speed reduction first begins at approximately 0.149 seconds after initial brake pedal application. (Figure 4)