

Study on Characteristics of Event Data Recorders in Japan; Analysis of J-NCAP and Thirteen Crash Tests

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ABSTRACT

Event Data Recorder (EDR) is a device to record vehicle and occupant information for a brief period of time before, during and after a crash event. EDR is one of the promising devices for accident reconstruction by recording important information e.g. vehicle speed, engine speed, brake switch, throttle and delta-V. However, in order to use EDR for an accident investigation, reliability and accuracy of those EDR data must be examined firstly. The aim of this study is to evaluate the characteristics of EDR and to understand the performance of EDR for the improvement of accident reconstruction with more reliable and accurate information on an accident in Japan. The analysis is based on J-NCAP crash tests from 2006 to 2009 with corresponding EDR datasets. Full-overlap frontal collision test and offset frontal collision test of fourteen car models were analyzed. The pre-crash velocity and the maximum delta-V data recorded in the EDRs are compared with the results from accelerometers and from high speed video cameras. In all cases, the pre-crash velocity recorded by the EDRs showed good reliability and accuracy. Moreover, thirteen crash tests were conducted to understand the performance of EDR under the situation of real world traffic accidents. The crash test types were frontal crash tests (collide to offset rigid barrier and concrete block), pole crash tests (front-center with iron pole, front-right with iron pole, right side with iron pole and front-center with concrete pole), car-to-car collision tests and multiple rear-end collision tests. The pre-crash velocities of EDRs showed good reliability excluding cases with full braking condition. Braking condition may influence the recording data as over

estimating. On the other hand, the EDR longitudinal delta-V from pole crash may indicate less reliability. Principle direction of force (PDOF) is estimated and evaluated using EDR recording data.

INTRODUCTION

Event Data Recorder (EDR) is an additional function installed in airbag control module (ACM) to record vehicle and occupant information for a brief period of time before, during, and after a crash event. In August 2006, the National Highway Traffic Safety Administration (NHTSA) in the USA published a final rule on Event Data Recorders (EDRs) [1]. In January 2008, NHTSA published a revised final rule on EDRs and responded to several petitions for reconsideration of the rule published in August 2006 [2]. In March 2008, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (J-MLIT) decided on the technical requirements for the application of EDRs to light vehicles (3500 kg GVWR or less) [3]. This rule-the so called J-EDR technical requirement-is comparable to the US regulation (49 CFR Part 563). EDRs are now being installed in ACMs by several automakers in the USA and in Japan.

EDRs are promising for accident reconstruction since they record delta-V, indicated vehicle speed, engine speed, driver seat position and driver safely belt status; furthermore, they verify whether or not the service brake was applied, to what extent the accelerator pedal was depressed (or engine throttle percentage). However, if EDRs are to be utilized for accident investigation, it is first necessary to examine the reliability and accuracy of data read out from EDRs.

The aim of this study is to evaluate the characteristics of EDRs and to understand the performance of EDRs for the improvement of accident reconstruction. The analysis is based on two types of crash tests. The first type is the J-NCAP crash tests, and the second type involves crash tests reconstructing typical real-world accidents. The pre-crash velocity, maximum delta-V, and delta-V time history recorded in the EDRs are compared with the results obtained from instrumented sensors and high-speed video cameras.

In the first paper [4], results of J-NCAP crash tests for seven models and three crash tests reconstructing typical real-world accidents were reported. Moreover, multiple rear-end collision and concrete pole accident are analyzed as case study [5, 6]. In this paper, results of J-NCAP crash tests for four models conducted in 2009 were added existing data and totally fourteen models conducted in 2006-2009 and thirteen crash tests reconstructing typical real-world accidents including the tests used in the first report were analyzed.

GENERAL DESCRIPTION OF ANALYSIS METHOD

Laboratory crash test data are used for the comparison of the EDR data. (See Figure 1)

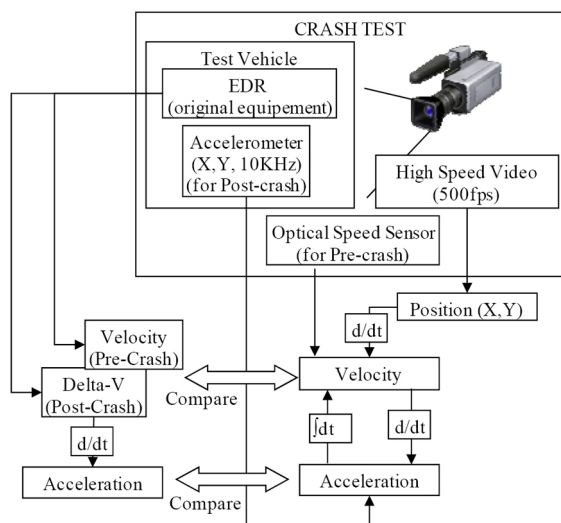


Figure 1. Diagram of data analysis.

According to the test procedures, three or four accelerometers are attached to the cars used for the tests, and high-speed video cameras are employed. The acceleration data obtained from the sensors are integrated to obtain the change in velocity, delta-V, during the collision. The displacement of the target marks on the cars captured by a high-speed video camera is differentiated to obtain the delta-V. An external optical speed sensor is employed to obtain the impact velocities of the cars.

Car models installed with EDRs are used for the analyses. The car velocities obtained as pre-crash data recorded in the EDRs are compared with the velocities obtained from the optical speed sensor and high-speed video cameras. The delta-V recorded in the EDR is compared with the delta-V calculated using the accelerometers and high-speed video cameras.

ANALYSIS OF J-NCAP CRASH TEST DATA

Twenty-eight separate crash tests involving fourteen vehicle models equipped with EDRs are analyzed.

ANALYSIS METHOD OF J-NCAP CRASH TEST DATA

The analysis was based on the data obtained from the J-NCAP full-overlap frontal barrier (FLB) tests conducted at 55 km/h along with 40% overlap offset frontal deformable barrier (ODB) tests conducted at 64 km/h in 2006-2009. All vehicle models are Toyota. The pre-crash velocity recorded in each EDR (V_{EDR}) was compared with the data obtained from the optical speed sensor placed in front of the barrier (V_{OP}). Compared pre-crash velocity was linked to impact. The maximum delta-V and delta-V time history recorded in the EDRs were compared with the J-NCAP test data obtained from three accelerometers-placed on the left-side sill (A-L), right-side sill (A-R), and center floor (A-C)-and from a high-speed video camera (Video). In this report, the delta-V is obtained by averaging the data from left and right accelerometers (Ave. of A-R and A-L).

PRE-CRASH EDR DATA IN J-NCAP CRASH TEST

Table 1 compares the results obtained for the pre-crash velocity. In all the cases, the difference between the EDR pre-crash velocity (V_{EDR}) and the J-NCAP test velocity (V_{OP}) is less than 7% (average: approximately 2% root mean square: approximately 3%).

Maximum absolute difference rate is 6.3% of Mv-4 and others are less than 4.1%. All absolute difference velocities including Mv-4 are less than 1 m/s. The pre-crash velocities of EDR were highly accurate and reliable but generally lower than the optically derived velocities (V_{OP}). A result of previous study [7] on EDRs shows that the difference between the pre-crash velocities was less than 1 mph in all the cases (average difference: 1.1%). The results in this paper are similar to the previous study.

Table 1. Comparison results of pre-crash velocity in J-NCAP FLB and ODB crash test.

Test	Model	V _{OP}	V _{EDR}	Difference	
		m/s	m/s	m/s	%
FLB	PC-1	15.3	15.0	-0.3	-2.0
	PC-2	15.3	15.6	+0.3	+1.9
	PC-3	15.3	15.0	-0.3	-2.0
	PC-4	15.3	15.0	-0.3	-2.0
	PC-5	15.3	15.0	-0.3	-2.0
	PC-6	15.3	15.0	-0.3	-2.0
	PC-7	15.3	15.0	-0.3	-2.0
	PC-8	15.3	15.0	-0.3	-2.0
	Mv-1	15.3	15.0	-0.3	-2.0
	Mv-2	15.3	14.9	-0.4	-2.7
	Mv-3	15.2	15.0	-0.2	-1.3
	Mv-4	15.3	14.4	-0.9	-6.3
	Mv-5	15.3	15.0	-0.3	-2.0
	Mv-6	15.3	15.0	-0.3	-2.0
	Average			-0.3	-2.0
	R. m. s.			0.4	2.6
ODB	PC-1	17.9	17.2	-0.7	-4.1
	PC-2	17.8	17.8	0.0	0.0
	PC-3	17.8	17.2	-0.6	-3.5
	PC-4	17.8	17.2	-0.6	-3.5
	PC-5	17.8	17.2	-0.6	-3.5
	PC-6	17.9	17.2	-0.7	-4.1
	PC-7	17.8	17.8	0.0	0.0
	PC-8	17.8	17.8	0.0	0.0
	Mv-1	17.9	17.8	-0.1	-0.6
	Mv-2	17.7	17.1	-0.6	-3.5
	Mv-3	17.7	17.2	-0.5	-2.9
	Mv-4	17.8	17.2	-0.6	-3.5
	Mv-5	17.8	17.8	0.0	0.0
	Mv-6	17.8	17.8	0.0	0.0
	Average			-0.4	-2.1
	R. m. s.			0.5	2.7
Average				-0.3	-2.1
Root mean square				0.4	2.6

POST-CRASH EDR DATA IN J-NCAP CRASH TEST

Table 2 and Table 3 compare the results for the post-crash maximum delta-V. The maximum delta-Vs recorded by the EDR (Max delta-V_{EDR}) shows uncertainty in measurement in several cases when compared with the results obtained from the reference values. Some reference data has large difference from EDR data and other reference data. Therefore, median of three reference data is selected as primary index for analysis to exclude dubious reference data. In the comparison between Max delta-V_{EDR} and median of reference values (Table 3), the difference is greater than 5% in nineteen of twenty-eight tests and greater than 10% in twelve of twenty-eight tests. Maximum absolute difference is 20.5% in ODB test of Mv-4(SUV). The root mean square of differences in the all maximum delta-Vs is approximately 10%. The maximum delta-V values recorded by the EDR are generally lower than the reference data.

Results of previous study [7] on EDRs show that the average difference in the maximum delta-V was approximately 6%, and in nearly all the cases, the maximum delta-V recorded by the EDRs was less than the delta-V obtained by the instrumented accelerometers. The results in this study show larger absolute difference than the previous study.

Figure 2 shows the relation of the differences in FLB and ODB for each vehicle model. As shown in Figure 2, the results could be broadly classified as two groups. It is assumed that the classes relates to types of vehicle model. The results of most of passenger cars are inside of 10% area of Figure 2, except PC-2, PC-3 and PC-8. The results of most of mini-vans are outside of 10% area. The results suggest that vehicle model type influenced the accuracy of EDR post-crash data. The body structural characteristics could be responsible for the result. This result shows that EDR post-crash data of passenger car type is more accurate than those of minivan type.

Figure 3 shows Delta-V time history curves in J-NCAP FLB and ODB crash tests. Two models are example of each group described above. PC-1 is the example of the group of less difference between maximum delta-V_{EDR} and reference values, and Mv-4 is the example of large difference group. All data show good agreement for PC-1, however data in Mv-4 are not in agreement.

Table 2. Results of reference post-crash maximum delta-V in J-NCAP FLB and ODB crash test.

Test	Model	V _{Video} (m/s)	V _{A-C} (m/s)	V _{Ave. A-R and A-L} (m/s)	Median of references (m/s)
FLB	PC-1	17.2	17.0	17.7	17.2
	PC-2	16.9	17.1	17.8	17.1
	PC-3	17.1	16.4	18.1	17.1
	PC-4	17.3	17.9	18.5	17.9
	PC-5	17.0	18.8	17.6	17.6
	PC-6	16.2	17.8	17.8	17.8
	PC-7	16.3	17.0	17.9	17.0
	PC-8	17.4	17.2	114.4	17.4
	Mv-1	17.1	21.4	17.1	17.1
	Mv-2	17.0	18.1	17.5	17.5
	Mv-3	16.7	19.6	17.1	17.1
	Mv-4	17.0	15.4	17.2	17.0
	Mv-5	16.6	15.3	17.5	16.6
	Mv-6	16.5	16.9	17.2	16.9
	Average	16.9	17.6	24.5	17.2
ODB	PC-1	20.3	19.0	19.3	19.3
	PC-2	19.4	22.1	19.4	19.4
	PC-3	20.0	21.7	19.4	20.0
	PC-4	20.7	20.2	19.9	20.2
	PC-5	20.1	19.4	19.4	19.4
	PC-6	20.0	18.5	19.5	19.5
	PC-7	17.3	24.3	19.6	19.6
	PC-8	17.3	16.9	19.7	17.3
	Mv-1	18.4	22.4	20.8	20.8
	Mv-2	19.9	18.8	20.1	19.9
	Mv-3	20.5	20.3	26.6	20.5
	Mv-4	20.5	29.8	19.4	20.5
	Mv-5	19.9	17.1	19.8	19.8
	Mv-6	20.6	19.8	20.2	20.2
	Average	19.6	20.7	20.2	19.7

Table 3. Comparison results of post-crash maximum delta-V in J-NCAP FLB and ODB crash test.

Test	Model	Median of references (m/s)	Max. delta-V _{EDR} (m/s)	Difference	
				m/s	%
FLB	PC-1	17.2	16.5	-0.7	-4.1
	PC-2	17.1	15.3	-1.8	-10.5
	PC-3	17.1	14.9	-2.2	-12.9
	PC-4	17.9	16.2	-1.7	-9.5
	PC-5	17.6	16.7	-0.9	-5.1
	PC-6	17.8	16.3	-1.5	-8.4
	PC-7	17.0	16.8	-0.2	-1.2
	PC-8	17.4	15.4	-2.0	-11.5
	Mv-1	17.1	14.7	-2.4	-14.0
	Mv-2	17.5	15.2	-2.3	-13.1
	Mv-3	17.1	15.2	-1.9	-11.1
	Mv-4	17.0	14.5	-2.5	-14.7
	Mv-5	16.6	14.7	-1.9	-11.4
	Mv-6	16.9	16.9	0.0	0.0
	Average			-1.6	-9.1
	R. m. s.			1.8	10.2
ODB	PC-1	19.3	19.1	-0.2	-1.0
	PC-2	19.4	19.2	-0.2	-1.0
	PC-3	20.0	18.4	-1.6	-8.0
	PC-4	20.2	18.7	-1.5	-7.4
	PC-5	19.4	18.7	-0.7	-3.6
	PC-6	19.5	19.0	-0.5	-2.6
	PC-7	19.6	17.8	-1.8	-9.2
	PC-8	17.3	19.2	1.9	11.0
	Mv-1	20.8	18.5	-2.3	-11.1
	Mv-2	19.9	17.5	-2.4	-12.1
	Mv-3	20.5	18.6	-1.9	-9.3
	Mv-4	20.5	16.3	-4.2	-20.5
	Mv-5	19.8	19.0	-0.8	-4.0
	Mv-6	20.2	20.5	0.3	1.5
	Average			-1.1	-5.5
	R. m. s.			1.8	9.0
Average				-1.4	-7.3
Root mean				1.8	9.6