

Brake Burnishing Effect on AEB Performance

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ABSTRACT

The Insurance Institute for Highway Safety (IIHS) evaluates autonomous emergency braking (AEB) systems as part of its front crash prevention (FCP) ratings. To prepare the test vehicles' brakes, each vehicle must have 200 miles on the odometer and be subjected to the abbreviated brake burnish procedure of Federal Motor Vehicle Safety Standard (FMVSS) 126. Other organizations conducting AEB testing follow the more extensive burnishing procedure described in FMVSS 135; Light Vehicle Brake Systems. This study compares the effects on AEB performance of the two burnishing procedures using seven 2014 model year vehicles.

Six of the vehicles achieved maximum AEB speed reductions after 60 or fewer FMVSS 135 stops. After braking performance stabilized, the Mercedes ML350, BMW 328i, and Volvo S80 showed increased speed reductions compared with stops using brand new brake components. The Acura RLX and Cadillac CTS showed no change in speed reductions, and the speed reductions of the Dodge Durango and Lexus IS 250 worsened.

After the FMVSS 135 burnishing was complete, AEB runs at 20 and 40 km/h were conducted to compare the results from the original IIHS FCP rating tests. For each of the vehicles, the IIHS FCP rating was not changed by different burnishing procedures.

Results show that AEB speed reductions can improve or degrade as new brakes progress through the FMVSS 135 burnishing cycle. However, the differences in either direction are small and none of the tested vehicles had speed reduction differences that were great enough to change the IIHS FCP ratings.

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INTRODUCTION

The Insurance Institute for Highway Safety (IIHS) has been evaluating the performance of autonomous emergency braking (AEB) systems on passenger vehicles in its front crash prevention program since the first ratings were released on September 27, 2013 [1]. The performance criteria are based on the average speed reduction that the vehicle attains for five valid runs at speeds of 20 and 40 km/h into a stationary EuroNCAP Vehicle Target (EVT). While the evaluation is only based on speed reductions at 20 and 40 km/h, IIHS evaluates AEB performance at speeds ranging from 10 to 50 km/h for research purposes. In order to ensure that the brakes of tested vehicles are in service condition before testing the AEB performance, IIHS protocol states that each vehicle must have between 200 and 5,000 miles on the odometer and must complete the brake warm-up procedure outlined in Federal Motor Vehicle Safety Standard (FMVSS) 126 [2]. The procedure involves 10 stops from 56 km/h at a deceleration of 5-6 m/s² and three stops from 72 km/h that activate the antilock braking system (ABS) [3]. AEB testing must commence after a 5 minute cool down drive at 56 km/h but no longer than 15 minutes after the last brake run.

The National Highway Traffic Safety Administration's draft procedure for crash imminent braking specifies a more extensive brake burnishing procedure [4]. The agency's evaluation uses the brake burnishing procedure outlined in FMVSS 135; Light Vehicle Brake Systems [5]. This procedure requires test vehicles to complete 200 brake stops from 80 km/h at a deceleration of 3 m/s². Brake rotor temperatures are also monitored throughout the burnishing sequence. If the temperature of the rotors exceeds 100°C, then the test vehicle must be driven 2 km to cool the brakes.

This study compares IIHS FCP performance after using the FMVSS 135 full burnishing procedure and the mini burnish procedure prescribed by the IIHS protocol. In addition, the study identifies the percentage change in AEB speed reduction at incremental steps throughout the FMVSS 135 burnishing procedure.

METHODS

Seven 2014 vehicles were selected, representing a wide range of vehicle manufacturers and including both sedans and SUVs. The 2014 Acura RLX, BMW 328i, Cadillac CTS, Dodge Durango, Lexus IS 250, Mercedes ML350, and Volvo S80 were selected in part because prior AEB test results using the IIHS protocol were known.

Burnishing Research

Each model was fitted with OEM replacement brake pads and rotors and tested using the FMVSS burnish procedure, with the exception that three repeated AEB tests were conducted at fixed steps in the burnishing sequence. [Table 1](#) outlines the test sequence used for all vehicles.

Table 1. Brake burnishing test sequence

Test Sequence	Cumulated Total Tests
1. 3 AEB tests	3
2. 20 FMVSS 135 brake runs	23
3. 3 AEB tests	26
4. 20 FMVSS 135 brake runs	46
5. 3 AEB tests	49
6. 20 FMVSS 135 brake runs	69
7. 3 AEB tests	72
8. 50 FMVSS 135 brake runs	122
9. 3 AEB tests	125
10. 75 FMVSS 135 brake runs	200
11. 3 AEB tests	n/a

While some of the vehicles selected for this study were capable of avoiding a collision with a stationary object at 20 km/h, none of them were capable of avoiding collisions across the entire range of 20-50 km/h recorded in IIHS testing. Speed reductions varied differently for each model across this range. This observation was used to increase the probability of measuring differences associated with the brake burnishing effect by testing each model at a different speed based on the known performance of each FCP system. The speed selected for the AEB tests interspersed amongst the brake burnishing runs was a speed close to 40 km/h at which large speed reductions not resulting in a collision avoidance occurred. This ensured a high possibility that changes in the speed reduction associated with the brake conditioning could be detected. [Table 2](#) shows the speed selected for each model along with the expected speed reduction at that speed. As the different models were tested at different speeds, the AEB braking performance is reported as the percent speed reduction from the initial test speed.

Table 2. Initial test speeds and expected speed reductions for each vehicle

Vehicle	Test speed (km/h)	IIHS FCP speed reduction (%)
RLX	30	48
328i	30	36
CTS	40	52
Durango	30	45
IS 250	35	57
ML350	40	56
S80	40	53

Brake temperature measurements required for FMVSS 135 were recorded using a Fluke VT02 Visual Infrared Thermometer to ensure they were below the acceptable tolerance of 100°C.

IIHS FCP Comparison

At the completion of the full FMVSS 135 burnishing procedure, each vehicle was subjected to five repeated AEB tests each at 20 and 40 km/h following the IIHS protocol.

RESULTS

Burnishing Research

During the modified FMVSS 135 procedure, six of the seven AEB vehicles achieved maximum speed reductions after 60 or fewer stops. The 328i achieved maximum speed reduction after 110 stops, however the speed reduction only increased by 2 percentage points compared with the performance after 60 stops. The maximum speed reductions were improvements for three of the vehicles compared with the expected speed reductions. After the braking performance stabilized, the ML350, 328i, and S80 saw speed reductions increase by 2, 3, and 4 percentage points, respectively. The RLX and CTS showed no change in reductions, and the Durango and IS 250 speed reductions worsened by 1 and 8 percentage points, respectively. As the brake burnishing process progressed, the spread of the speed reductions did not become more consistent despite the increased number of brake runs. Generally, each vehicle tested had a spread of about 5 percentage points in the reductions for each set of repeated AEB runs. The RLX had several outlying runs that were excluded from the data due to inconsistencies in performance of its AEB system. [Table 3](#) compares the results for each vehicle, while [Appendix A](#) shows graphs of the changing AEB performance for each vehicle throughout the burnishing procedure.

Table 3. Results of brake burnishing research compared to expected results

Vehicle	Test speed (km/h)	Peak speed reduction FMVSS 135 Procedure		IIHS FCP speed reduction (%)	Difference
		Stops	Speed reduction (%)		
RLX	30	20	48	48	0
328i	30	110	39	36	+3
CTS	40	60	52	52	0
Durango	30	0	44	45	-1
IS 250	35	40	49	57	-8
ML350	40	60	58	56	+2
S80	40	40	57	53	+4

IIHS FCP Comparison

For all of the vehicles, the IIHS FCP ratings remained the same when subjected to the two different burnishing procedures. In many cases, the speed reductions were lower after completing the entire FMVSS 135 procedure compared with the speed reductions recorded using the current IIHS FCP brake burnishing protocol. At 20 km/h, the RLX, ML350, IS 250, and Durango had better results in the original IIHS FCP rating tests compared with retests using the FMVSS 135 brake burnishing. The S80, CTS, and 328i had speed reductions within 0.1 km/h. At 40 km/h, the CTS, RLX, IS 250, and Durango had better results by at least 1.0 km/h in the original FCP testing. The 328i had speed reductions at 40 km/h within 0.1 km/h. The S80 and ML350 at 40 km/h were the only vehicles that had increased speed reductions after completing the FMVSS 135 brake burnishing. They reduced the impact speed by 1.9 and 0.3 km/h, respectively. [Figures 1](#) and [2](#) compare the average speed reductions for official IIHS FCP runs with the abbreviated burnish compared with the average speed reductions taken after the full FMVSS 135 burnishing procedure.

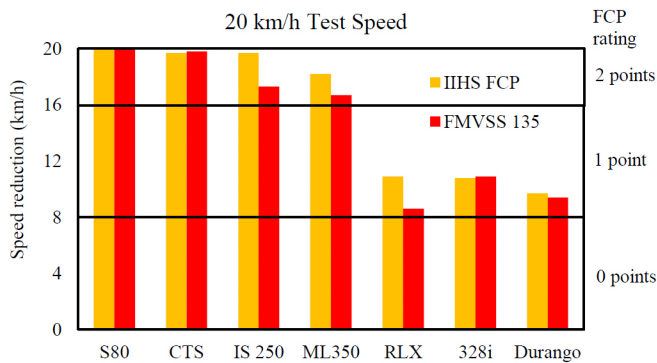


Figure 1. 20 km/h AEB test results with IIHS and FMVSS 135 burnish procedure

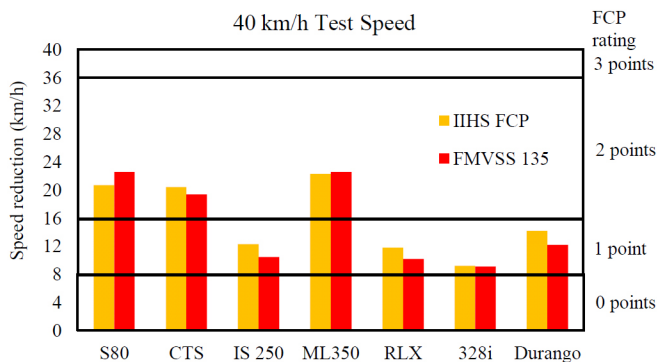


Figure 2. 40 km/h AEB test results with IIHS and FMVSS 135 burnish procedure

Appendix B contains graphs of the speed reductions for each run of the test vehicles relative to the IIHS FCP rating limits. For all of the vehicles, except the IS 250 and ML350, the spread of speed reductions at 20 and 40 km/h fell within a rating boundary. In both brake burnish scenarios at 40 km/h, the IS 250 had test runs fall below a rating boundary. After the FMVSS 135 burnish at 20 km/h, the ML350 had two out of five runs fall below a boundary. However, all five runs were within the same rating boundary after the IIHS FCP burnish. Despite there being several test runs that had speed reductions fall below a rating boundary, the average speed reductions for the IS 250 at 40 km/h and the ML350 at 20 km/h fell within the same rating boundaries. More information about the point system for IIHS FCP ratings can be found on the IIHS website [6].

DISCUSSION

This study shows that the performance of AEB systems are indeed dependent on the burnish level of the vehicle's brakes. However, each vehicle was able to attain their maximum performance prior to completion of the full FMVSS 135 procedure, which means, for practical considerations, an abbreviated burnish procedure can be used.

These results are based on only seven different vehicles. Results for other vehicles may vary from the results reported here. Nevertheless, the mix of brands and vehicle types in this study provides some assurance that the results are reasonably representative of 'typical' brake performance in the fleet.

Variation in brake performance throughout the burnishing procedure was greater than the variation observed in the repeated AEB tests for most models. However, most vehicles experienced the majority of their braking changes after only 20 stops. After 20 stops, the variation in repeated tests was about equal to the variation due to additional burnishing. It is reasonable to assume that the IIHS protocol requirements of a minimum of 200 road miles and the warm-up braking procedures assure a vehicles' brakes have largely stabilized.

For every vehicle tested, the speed reductions after the FMVSS 135 burnish resulted in the same IIHS FCP rating. The rating boundaries at 8 and 16 km/h for the 20 km/h test speed, and 8, 16, and 36 km/h for the 40 km/h test speed are far enough apart to not be affected by the variations resulting from the two burnish procedures.

CONCLUSIONS

Seven different vehicles were chosen to evaluate the effect of brake burnishing on the performance of AEB systems. With the exception of the Dodge Durango, every vehicle saw its performance gradually improve during the burnishing process then reach its maximum level prior to achieving the maximum number of burnish tests prescribed by FMVSS 135. Most vehicles reached their maximum AEB performance within 60 of the 200 prescribed brake stops. Results show that regardless of brake burnishing procedure, AEB tests at 20 and 40 km/h would earn the same rating points in the IIHS FCP rating system for all seven models tested. This suggests that the abbreviated burnish procedure contained in the IIHS FCP protocol is adequate to accurately rate and compare AEB performance.

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