Procedure for assessing the performance of Autonomous Emergency Braking (AEB) systems in front-to-rear collisions

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CONTENTS

1 AIM

This procedure specifies a method for assessing the performance of Autonomous Emergency Braking (AEB) systems in avoiding or mitigating front-to-rear collisions between vehicles.

2 SCOPE

The test scenarios in this procedure are applicable to passenger cars (category M1) with an Autonomous Emergency Braking (AEB) system.

The tests are conducted against an impactable car target that replicates a real vehicle in terms or its radar, visual and light reflective attributes, however the design intent of the systems must be to prevent or mitigate collisions with real vehicles in typical real world traffic situations.

3 BACKGROUND AND RATIONALE

Analysis of insurance claims databases (IIHS, 2012) has shown that forward collision warnings can have a substantial effect in reducing the frequency of crashes and that these reductions can be even greater where AEB is also fitted. Analysis of in-depth accident data (Lenard, J. et al., 2010; Kühn, M. et al., 2009; Roth, F. et al., 2009) has identified clusters of front to rear crashes where such systems would be expected to offer benefits. Physical experimentation and research based on the crash mechanisms identified by the in-depth accident research has shown that the performance of different systems and different technologies in these circumstances varies considerably.

The rationale for the development of this test procedure was therefore to create a standardised set of conditions that would enable the objective and repeatable assessment of AEB systems within scope and allow the performance to be reliably quantified.

4 OBJECTIVES

To produce objective, repeatable and reproducible results that quantify the performance of AEB systems in circumstances representative of the most common, real-world, car front to car rear collisions.

5 DEFINITIONS

Autonomous Emergency Braking (AEB) – braking that is applied automatically by the vehicle in response to the detection of a likely collision when the driver has not made any manual application of the brakes.

Car-to-Car Rear Stationary (CCRs) – a crash scenario in which the front of the test car collides with the rear of another stationary car positioned directly in front of the test car.

Euro NCAP Vehicle Target (EVT) – means the vehicle target with an appropriate radar and light reflective and visual signature intended for use in this protocol as described in section 6.

Time To Collision (TTC) – for the purposes of this test, means the instantaneous distance to the collision position divided by the instantaneous forward vehicle speed.

6 CAR TARGET

The car target used for the AEB tests shall have the appropriate radar and light reflective and visual signature of that of a real vehicle, equivalent to that of the Euro NCAP Vehicle Target (EVT) as described in Annex A of the Euro NCAP Test Protocol – AEB systems (http://www.euroncap.com/files/AEB-Test-Protocol---v1.0---0-84f3008e-1e2e-4ee5-8e7b-186363aec79c.pdf) as shown in Figure 1.

Figure 1 – Euro NCAP Vehicle Target (EVT)

7 TEST VEHICLE PREPARATION

7.1 General

Tests shall be undertaken using a new vehicle in the 'as received' condition. It is permitted that prior to being used for testing the vehicle may be driven a maximum of 5000km or equivalent as recorded by the odometer.

Prior to starting preparation and testing make sure:

1. All vehicle systems are activated to customer delivery format (i.e. the vehicle is not in pre-delivery mode).
2. Any deployable pedestrian protection systems are deactivated.
3. All fluids are correctly filled to the vehicle handbook specification.
4. The vehicle fuel tank is to at least 90% of capacity, and fuel is maintained to at least 75% of capacity throughout the testing.
5. The vehicle is in a safe working order.

7.2 Tyres

Tests shall be undertaken using new, original equipment, all weather (not winter) tyres of the make, model, size, speed and load rating as fitted by the manufacturer to the majority of the vehicles produced of the particular variant tested. It is permitted to test using tyres which are supplied by the manufacturer or acquired at an official dealer representing the manufacturer if those tyres are identical make, model, size, speed and load rating to the original fitment.

Inflate the tyres to the vehicle manufacturer's recommended tyre inflation pressure(s) as specified on the tyre inflation pressure placard or in the vehicle handbook, acknowledging the vehicle loading condition for the testing.

7.3 Instrumentation

Install data measurement and acquisition equipment to sample and record test vehicle dynamic data with a minimum accuracy of:

Measurement	Range	Accuracy
Longitudinal and lateral position	Relative to local datum	0.03m
Forward speed	0 to 60km/h	0.1km/h
Longitudinal acceleration	±20m/s^2	0.1m/s^2
Yaw rate	±30°/s	0.1°/s
Steering wheel angle or velocity (optional)	±180º or ±90º/s	1.0º or 1.0º/s
Accelerator pedal position (optional)	100% of pedal travel	0.1%
Contact with car target	-	Nearest data point

Table 1 – Instrumentation

Sample and record all dynamic data at a frequency equal to or greater than 100Hz.

8 TEST ENVIRONMENT

8.1 Surface and markings

Conduct tests on a dry (no visible moisture on the surface), uniform, solid-paved surface with a consistent slope between level and 2%.

The surface must not contain any significant irregularities (e.g. large dips or cracks, manhole covers, or reflective studs) that may give rise to abnormal sensor measurements within a lateral distance of 3m either side of the test path or with a longitudinal distance of 30m beyond the position at which the test finishes.

8.2 Surroundings

Tests shall be undertaken such that there are no other vehicles, highway furniture, obstructions or other objects protruding above the test surface that may give rise to abnormal sensor measurements within a lateral distance of 3m either side of the test path or within a longitudinal distance of 30m beyond the position at which the test finishes. Any overhead signs, bridges, gantries or other significant structures must be at a height of at least 5m above the test surface.

8.3 Ambient conditions

Test only in dry daylight conditions with ambient temperature between 5ºC and 40°C and horizontal visibility at ground level shall be greater than 1km. Average wind speeds shall be less than or equal to 10m/s to minimise car target and test vehicle disturbance.

9 TEST VEHICLE PRE-TEST CONDITIONING

9.1 Brakes and tyres

Prepare the vehicle's brakes in the following manner:

1. Perform ten stops from a speed of 56km/h with an average deceleration of approximately 0.5 to 0.6g.
2. Immediately following the series of 56km/h stops, perform three additional stops from a speed of 72km/h, each time applying sufficient force to the pedal to operate the vehicle's antilock braking system (ABS) for the majority of each stop.

3. Immediately following the series of 72km/h stops, drive the vehicle at a speed of 72km/h for five minutes to cool the brakes.

After conditioning maintain the tyres in the same position on the vehicle throughout the testing.

10 AEB SYSTEM TESTING

10.1 Car-to-car front-to-rear collision test scenario

The AEB system is assessed in the common car-to-car front-to-rear collision test scenario which evaluates the performance when the front of the test car is on a collision path with the rear of another stationary vehicle positioned directly in front of the test car in daylight conditions, as shown in Figure 2Figure 2 – Car-to-car front-to-rear collision test scenario

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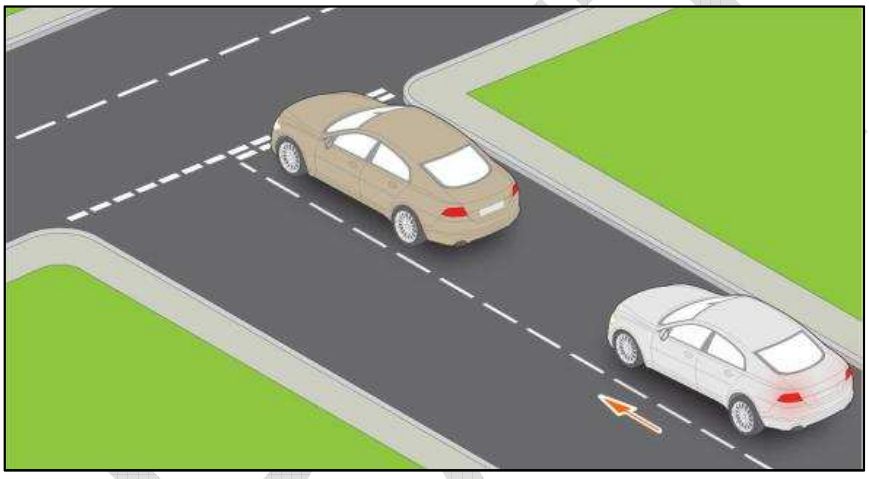

Figure 2 – Car-to-car front-to-rear collision test scenario

The performance of the test vehicle in the test scenario is evaluated over the typical rear world collision speed range from 10 to 50km/h in 5km/h increments. Perform tests with the longitudinal centrelines of the car target and test vehicle aligned on the test path representing a full overlap car-to-car front-to-rear collision.

10.2 Test method

Before every test run manoeuvre the test vehicle such that the car target is completely out of the field of view of the AEB sensor system (e.g. by driving the test vehicle in broadly the opposite direction to the test path away from the car target) and then manoeuvre the test vehicle into position on the test path with a longitudinal range in excess of 150m to the collision point with the test target. Bring the test vehicle to a halt on the test path and push the brake pedal through the full extent of travel and release.

For vehicles with an automatic transmission select D. For vehicles with a manual transmission select the highest gear compatible with the test speed that does not cause the engine to labour. When testing vehicles with a manual transmission do NOT depress the clutch pedal at any time during the test. The engine may stall during the test when testing vehicles with a manual transmission.

Manoeuvre the test vehicle as necessary to track along the test path and at the required speed. Use only manipulation of the accelerator and clutch pedals and transmission as necessary to modulate the test vehicle speed. If fitted, a speed limiting device may be used to maintain the test vehicle speed providing it does not interfere with the performance of the AEB system. Apply only minor steering inputs as necessary to maintain the test vehicle tracking along the test path.

Continue to maintain accelerator pedal position to achieve the speed throughout the test until automatic braking reduces the speed by 5km/h, at which point fully release the accelerator pedal as quickly as possible. Ensure the modulation of the accelerator pedal does not override the automatic braking system.

Do NOT apply the test vehicle brakes at any time throughout an AEB system test unless necessary to maintain a safe testing environment. The application of the brakes at any time throughout an AEB system test run invalidates the test run.

The end of the test is when the test vehicle either impacts the car target OR comes to a halt thus avoiding an impact.

Start testing with an initial approach speed of 10km/h. Where the test vehicle avoids a collision with the car target increase the test speed in 10km/h increments. Where an impact occurs between the test vehicle and car target the avoidance or impact performance must be found to the nearest 5km/h test speed increment. When an impact occurs continues testing in 5km/h increments to identify the impact speed mitigation performance. It is recommended that the testing ends when a speed reduction of less than 5km/h is achieved at a test speed.

Perform the first test between 3 and 15 minutes after completing the tyre conditioning. Subsequent tests must also be performed between 3 and 15 minutes after completing the previous test. If the time between consecutive tests exceeds 15 minutes perform three stops from 72km/h with approximately 0.5 to 0.6g deceleration and then restart testing.

Between tests, drive the test vehicle at a maximum speed of 50km/h and avoid riding the brake pedal and harsh acceleration, braking or turning unless strictly necessary to maintain a safe testing environment, the objective being to maintain the braking system in a cool condition.

For test speeds where a collision with the car target is avoided, two valid tests are required for confirmation. For test speeds where the test vehicle impacts the car target at a reduced speed, three valid tests are required to determine the mean speed reduction. For test speeds where there is an impact with the car target at the test speed with no automatic braking, two valid tests are required for confirmation.

10.3 Test tolerances

In order to achieve consistent test results for a test run to be valid, the following test approach conditions shall be achieved over the period from 4s TTC to when the vehicle begins to automatically brake.

Parameter	Tolerance
Approach speed	Nominal +1.0km/h*
Yaw velocity	±1.0°/s
Lateral deviation from test path	±0.10m ideally ±0.30m acceptable however additional test repeats may be required to confirm performance
Steering wheel velocity (optional)	±15.0°/s

Accelerator pedal position (optional)	Mean ±2%

Table 2 – Test tolerances

*Note that if the test vehicle gives a short duration deceleration jerk as part of a collision warning process, the test approach speed may fall below the nominal test speed. In such cases the approach speed must remain in tolerance up to the time of the deceleration jerk and is permitted to drop out of the tolerance thereafter.

11 DATA PROCESSING AND ANALYSIS

11.1 Speed

Use data as recorded.

11.2 Longitudinal acceleration

Filter the unfiltered longitudinal acceleration data with a 12 pole phaseless Butterworth filter with a cut off frequency of 6Hz. Zero the filtered data to remove sensor offset using the static pre-test data. Correct longitudinal acceleration relevant to the ground plane by removing the effects of vehicle body pitch under braking.

To determine when continuous pre-impact braking starts, find the first data point where the filtered and zeroed longitudinal acceleration is less than -1.0m/s^2 to confirm the vehicle is decelerating, and then inspect previous data points to find the first data point where the longitudinal acceleration is less than -0.3m/s^2. The first data point where the longitudinal acceleration is less than -0.3m/s^2 is the start of automatic braking.

11.3 Yaw velocity

Filter the unfiltered yaw velocity rate data with a 12 pole phaseless Butterworth filter with a cut off frequency of 6Hz. Zero the filtered data to remove sensor offset using the static pre-test data.

11.4 Lateral and longitudinal position

Use data as recorded.

11.5 Steering wheel velocity (optional)

Use data as recorded.

11.6 Accelerator pedal position (optional)

Use data as recorded.

12 AEB SYSTEM DEACTIVATION

A driver selectable deactivation of the AEB system is permitted providing that the following requirements are met:

1. The method of deactivating the AEB system is a conscious act by the driver that requires two or more distinct actions or selections OR requires a single action of at least 2.0s duration.
2. When the AEB system is deactivated a constant visual warning shows on the instrument cluster information panel to inform the driver.
3. The AEB system is automatically reinstated at the start of each new ignition cycle.

13 REFERENCES

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