



Vehicle Sensitivity to Brake Pulsation

1 Introduction

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This standard describes objective measurement of brake pulsation in terms of amplitude and frequency at standard driver interface locations.

1.2 Applicability. To passenger cars, multipurpose vehicles and light trucks.

1.3 Remarks. In 1993, GM North America (GMNA) Vehicle Development initiated work to develop a standard objective test to evaluate vehicle sensitivity to brake pulsation induced by rotor thickness variation (RTV) or drum roundness variation (DRV). Data from such a test would provide a basis for establishing drum and rotor component specifications. In addition, GM would have a means of evaluating vehicle modifications intended to improve vehicle robustness to brake pulsation.

GMNA Tire-Wheel Systems (TWS) has developed the Vehicle Vibration Sensitivity to Tire Wheel System Forces Measurement Procedure GMW14404 which has proven useful in the evaluation of vehicle sensitivity to tire/wheel forces. GMW14919 is a modification of GMW14404 used to objectively measure and diagnose brake pulsation vehicle issues. These measurements can be used to quantify the level of brake pulsation for various brake rotors and brake drums, to determine the contribution of brake rotors/drums, wheels, and bearing to the brake pulsation, and to assess vehicle sensitivity to brake irregularities.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

FMVSS 135

2.2 GM Standards/Specifications.

GMW14404 GMW15191

2.3 Additional References.

Julius S. Bendat & Allan G. Piersol (1993). Engineering Applications of Correlation and Spectral Analysis. New York: Wiley-Interscience.

Vehicle Technical Specifications (VTS)

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.3 This test procedure requires repeated low deceleration ($G = 9.807 \text{ m/s}^2$) brake stops from 115 km/h to 145 km/h. The test facility must have a track where such stops are permitted.

3.1.4 The test facilities and equipment shall be in good working order and shall have a valid calibration label.

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3.1.4 Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this specification shall be determined correctly with respect to its physical definition.

3.2 Equipment.

3.2.1 Seat bottom fixture accelerometer array.

3.2.2 Seat back fixture tri-axial accelerometer.

3.2.3 Floor feet fixture servo-type tri-axial accelerometer.

3.2.4 Tri-axial accelerometers.

3.2.5 Four (4) optical sensors.

3.2.6 Computer data acquisition system.

3.2.7 Signal conditioning system.

3.2.8 Decelerometer.

3.2.9 Water ballast dummy.

3.2.10 Brake friction material thermocouples.

3.3 Test Vehicle/Test Piece. As selected for test.

3.4 Test Time.

Calendar time: (1 to 2) days for each vehicle condition

Test hours: (6 to 8) h for each vehicle condition

Coordination hours: (4 to 6) h

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. The test requires a trained technician certified to complete the instructions in paragraph 4.

4 Procedure

4.1 Preparation.

4.1.1 Instrument the vehicle as instructed in GMW14404. The installation includes:

4.1.1.1 Accelerometers at the driver's side floor, seat bottom, seat back, steering wheel, steering column, brake pedal, and left outboard seat track. The driver's side floor accelerometer must be able to measure a nearly constant acceleration.

4.1.1.2 Tri-axial accelerometers on each spindle as near as possible to the wheel spin axis.

4.1.1.3 Optical sensors at each wheel position to provide a once-per-rev signal.

4.1.1.4 Computer data acquisition system.

4.1.1.5 Signal conditioning system.

4.1.1.6 Thermocouple installed to the brake friction material following the instructions in FMVSS 135. Install the brake hardware.

4.1.2 Additional accelerometer locations may be used at the discretion of the test engineer. As an example, the right rear (RR) seat track is commonly used in the evaluation of vans. When measuring the movement of an unoccupied seat, it is recommended to use a water ballast dummy to simulate a passenger in that seat.

4.1.3 The brake pulsation test procedure also requires a decelerometer in a location easily viewed by the driver during the braking action. This device is used to allow the driver to brake at a specified rate.

4.2 Conditions. This standard is intended to assess the vehicle in the "as-received" condition and with intentionally elevated levels of RTV and DRV. However if specific features or components are being evaluated, these should be documented by the requesting engineer in the procedure execution request form.

4.2.1 Environmental Conditions. The optical sensors are easily disabled by water and dust requiring that the test be run on only clean, dry roads. Temperature conditions are at the discretion of the requesting engineer but are generally limited to $> +10^{\circ}\text{C}$.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

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4.2.2.1 Each test shall consist of no fewer than 10 brake stops from 115 km/h to 0 km/h for each brake deceleration level (higher initial velocities as outlined in GMW14404 may also be used).

4.2.2.2 The test sequence should be conducted with rotors and pads that were burnished per FMVSS 135. Five vehicle sets (or axle sets if only front or rear brake corners are of interest) of rotors with machined RTV are recommended for passenger cars and light trucks as outlined in Table 1 or as specified in the applicable Vehicle Technical Specifications (VTS). When rotor thickness variation is machined into rotors, care should be taken to maintain the same level of rotor lateral runout (LRO) and surface finish that is specified for the production rotor.

Table 1: Recommended Rotor Thickness Variation Levels for Passenger Cars and Light Trucks

Passenger Car RTV Level (μm)	Light Truck RTV Level (μm)
As-Received, $\approx$ (1 to 4) μm , (1 st Order)	As-Received, $\approx$ (1 to 4) μm , (1 st Order)
10 (1 st Order)	10 (1 st Order)
10 (2 nd Order)	10 (2 nd Order)
20 (1 st Order)	20 or 30 (1 st Order)
20 (2 nd Order)	20 or 30 (2 nd Order)

4.2.2.3 If accelerometers are placed on unoccupied seats or seat tracks, the seat should be occupied by a ballast dummy.

4.3 Instructions.

4.3.1 Test Track. The test procedure described is for the Oval Track at the Milford Proving Ground, Milford, Michigan, United States of America. Similar test procedures could be designed for other road systems. The objectives of the test design are:

4.3.1.1 Use a road system that excites the brake pulsation response.

4.3.1.2 Obtain at least 10 braking events per deceleration range and RTV level that are spaced over enough driving distance to allow for independent corner vibration source identification, that is, insignificant cross-coherence among the four corners.

4.3.1.3 Obtain at least 10 steady-state events per deceleration range and RTV level that are spaced over enough driving distance to allow for independent corner vibration source identification, that is, insignificant cross-coherence among the four corners.

4.3.1.4 Use of brake thermocouples and an initial brake temperature is to prevent overheating of the brake system.

4.3.1.5 Repeat testing, with drums and rotors indexed relative to the spindle, is done so that component contributions may be assessed.

4.3.2 Data Sampling Parameters. The data are sampled at 256 samples/s for 10.1 s. The sample time was based on the time required to stop from 115 km/h at a deceleration rate of 0.2G, but this time can be varied to accommodate the recommended deceleration levels and/or higher initial velocities.

4.3.3 Braking Procedure. The braking procedure is designed for light to moderate braking conditions similar to what one would experience exiting a highway. The braking deceleration rates are 0.1G, 0.2G, and 0.3G from a minimum initial velocity of $\approx$ 115 km/h to 0 km/h. A higher initial velocity such as those outlined in GMW14404 may be used as well. Though moderate, this type of braking leads to in-stop brake temperature rise. An initial brake temperature (IBT) of $(+100 \pm 10)^\circ\text{C}$ should be attained before the beginning of each snub by performing warming snubs or brake cooling laps as outlined in GMW15191. The braking process is as follows:

4.3.3.1 Accelerate to $\approx$ 115 km/h, then allow the vehicle to coast down.

4.3.3.2 Begin taking data at $\approx$ 109 km/h.

4.3.3.3 Apply brake at 105 km/h and hold deceleration at the specified deceleration level (i.e., 0.1G, 0.2G, or 0.3G).

4.3.3.4 Release brake at $\approx$ 0 km/h.

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