



Brake Component Experimental Modal Analysis

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. To determine the free-free disc brake corner component natural frequencies and mode shapes from 0.1 kHz to 17 kHz through experimental modal analysis. This modal data is used to correlate and update analytical models developed using Brake Noise Analysis Procedure 20-04-008. In addition, this standard is also used to develop countermeasures for brake squeal identified in GMW14591, GMW17427 and/or GMW16417.

1.2 Applicability. This standard is applicable to all passenger car and light truck front and rear brake corners.

1.3 Remarks. This standard is intended to quantify the brake corner assembly structural dynamics to benefit brake noise performance.

2 References

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

2.1 External Standards/Specifications.

SAE J2598

SAE J2933

2.2 GM Standards/Specifications.

GMW14181

GMW14229

GMW15273

GMW17427

GMW14196

GMW14591

GMW16417

2.3 Additional References.

Brake Noise Analysis Procedure 20-04-008

3 Resources

3.1 Facilities. Milford Proving Ground Brake Measurement Lab facility or equivalent Test Improvement Process accredited test facility shall be used. A bedplate/test room consisting of any interior environment with a hard level surface to isolate the test piece and test equipment from background vibration levels that facilitate coherence values > 0.95 at all Frequency Response Function (FRF) maximum over the frequency range of interest.

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.

3.2 Equipment. GMW14181 lists and describes the required equipment. Additional equipment includes:

3.2.1 GMW14196 closed-cell polyurethane foam large enough to support the brake corner component under test. A photograph of the foam is shown in Appendix A, Figure A1.

3.2.2 An impact hammer is recommended for all force inputs, however, a shaker may be used for rigid or in-situ testing, if hammer force input levels and/or input force spectrum characteristics outlined in GMW14181 are not sufficient. Specific requirements for the hammer(s), optional shaker(s), and transducers are contained in Appendix A, Table A1 of this standard.

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3.3 Test Vehicle/Test Piece. Representative brake corner component hardware (i.e., bearing, rotor, caliper, or drum) supported by compliant springs (e.g., GMW14196 polyurethane foams). Based on prior component test experience and modal test data usage (e.g., component Finite Element (FE) model correlation) it is recommended to perform a free-free mounting condition.

3.4 Test Time.

Calendar time: 1 d
Test time: 4 h
Coordination time: 1 h part preparation

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. One (1) technician and/or one (1) engineer trained in noise and vibration data acquisition, analysis, equipment use, and test setup is required.

4 Procedure

4.1 Preparation. Reference GMW14181. If using a laser doppler vibrometer, the component's surface can be sprayed with leak trace powder to improve signal reflectivity.

4.2 Conditions.

4.2.1 Environmental Conditions. Reference GMW14181.

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.

4.3 Instructions.

4.3.1 Set and maintain the data acquisition parameters as recommended in GMW14181 in addition to the following:

- Minimum frequency bandwidth should be set between 0 kHz to 17 kHz (certain geometry and/or componentry may result in a maximum frequency lower than 17 kHz).
- Minimum frequency sampling rate shall be greater than twice the total acquisition frequency bandwidth.
- A minimum of three (3) averages per measurement point.
- 8 Hz frequency resolution (minimum recommended).
- Uniform window should be used exclusively if modal damping is to be reported.

4.3.2 Mount triaxial (or uniaxial in successive directions) accelerometers or specify laser doppler vibrometer measurement points as appropriate to uniquely identify brake component (rotor, caliper housing, caliper bracket, and pad) modes up to 17 kHz. A sample disc brake corner geometry with component geometry and sample laser vibrometer measurement points are shown in Appendix B, Figures B1 through B7 for major disc brake components. See SAE J2933 for further recommendations on setup configurations. Measurement point placement guidelines (minimum number) are as defined in 4.3.2.1 through 4.3.2.6.

4.3.2.1 Rotor. A minimum of 40 points placed similarly on the rotor's brake plate as shown in Appendix B, Figure B2.

4.3.2.2 Pad. One (1) point at each corner and center of the backing plate, depending on accessibility (five (5) measurement points per pad). See SAE J2598 for further recommendations on measurement point locations.

4.3.2.3 Caliper Housing. One (1) point at each corner of the caliper bridge with several points across the interior of the bridge, one point on each finger, one on each caliper ear, and one near the piston housing (ten (10) measurement points).

4.3.2.4 Caliper Bracket. One (1) point on each bend in the bracket and one (1) point every 40 mm in between (ten (10) measurement points).

4.3.2.5 Others, as necessary, to define the brake corner geometry and prevent spatial aliasing and any extraneous components, if attached to brake component, that significantly effect component modal analysis. The use of a 2 Dimensional (2D) laser vibrometer may also allow for and, in many instances, require additional measurement points in order to identify modes.

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4.3.2.6 Finite Element model correlation may require additional measurement points for correlation and should be identified through a pretest measurement point analysis as outlined in Brake Noise Analysis Procedure 20-04-008.

4.3.3 Document the measurement geometry.

4.3.4 Recommended impact hammer force input points are shown in Appendix C for all major disc brake corner components in the free-free condition. Similar force input points may be used for rigid or in-situ testing. The hammer impact direction can be at an oblique angle to excite all of the component modes. However, certain component geometry and/or with the use of acquisition equipment may require the use of discrete orthogonal impact hammer directions and/or multiple input force locations in order to excite and/or appropriately identify all of the brake component modes. Particularly, if performing experimental modal analysis on rotors with a Three Dimensional (3D) laser vibrometer or triaxial accelerometers, if the modes of interest are Nodal Diametrical (ND) modes, the impact direction should be applied axially. However, if the modes of interest are In-Plane Compressional (IPC) modes, the impact direction should be applied tangentially or radially. See Appendix C, Figures C1 through C5 as an example to the impact location and direction.

4.3.5 Identify sufficient impact hammer force levels and acquire FRFs, per GMW14181.

4.3.6 Brake component modal analyses using rigid or in-situ boundary conditions may require a shaker force input. The acquisition parameters, test instructions and equipment outlined in GMW15273 should be used for any brake component modal analysis requiring a shaker input. However, care should be taken in selecting force input points on components and may require multiple input force locations in order to excite all of the brake component modes.

5 Data

5.1 Calculations. Determine the natural frequencies and mode shapes of each brake corner component from 0.1 kHz through 17 kHz using the process specified in GMW14229. For rotors, at minimum, identify the frequencies of 2nd through 10th ND modes; 1st, 2nd, and 3rd IPC modes. See Appendix D, Figures D1 and D2. For FE component model correlation, specify normal/real modes during modal parameter estimation.

5.2 Interpretation of Results. Complete a mode summary table and produce summation FRF plots for each of the corner components as outlined in GMW14229. In particular, the mode summary table should be completed for modes within 500 Hz of any squeal frequencies identified analytically (Brake Noise Analysis Procedure 20-04-008) or experimentally (GMW14591). Also include any pictures or animations of mode shapes of interest (e.g., near brake squeal frequency). Example mode summary tables are shown in Appendix D, Tables D1 and D2.

5.3 Test Documentation. Document all test information in 5.2. Document all available information on the measured component. Examples of hardware information to document are shown in Appendix D, Tables D3 and D4.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

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7 Notes

7.1 Glossary. Not applicable.

7.2 Acronyms, Abbreviations, and Symbols.

@	at
#	Number
FE	Finite Element
FRF	Frequency Response Function
GSSLT	Global Subsystem Leadership Team
IPC	In-Plane Compressional
IPR	In-Plane Radial
ND	Nodal Diametrical

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW15632

9 Release and Revisions

This standard was originated in July 2007. It was first approved by the Global Chassis Brake Subsystem Leadership Team in July 2007. It was first published in October 2007.

Issue	Publication Date	Description (Organization)
1	OCT 2007	Initial publication.
2	NOV 2012	Added references SAE J2933 and GMW16417. Confined the applicability of this procedure to experimental modal analysis. Expanded the applicability of this procedure to include rigid mounting. Defined applicable frequency range as from 0.1 to 17 kHz. Defined additional acquisition parameters (paragraph 4.3.1). Defined minimum required number and placement of measurement points for rotor (paragraph 4.3.2.1). Specified required rotor modes to perform parameter estimation for frequencies and percent critical damping (paragraph 5.1). Specified test documentation requirements (paragraph 5.3). In appendices updated Figures B2, B3, C1, D1 and D2. In appendix updated Tables D2, D3, and D4. (Global Brake GSSLT)
3	APR 2018	Revised to current template. (Chassis Brake Global Subsystem Leadership Team (GSSLT))

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Appendix A

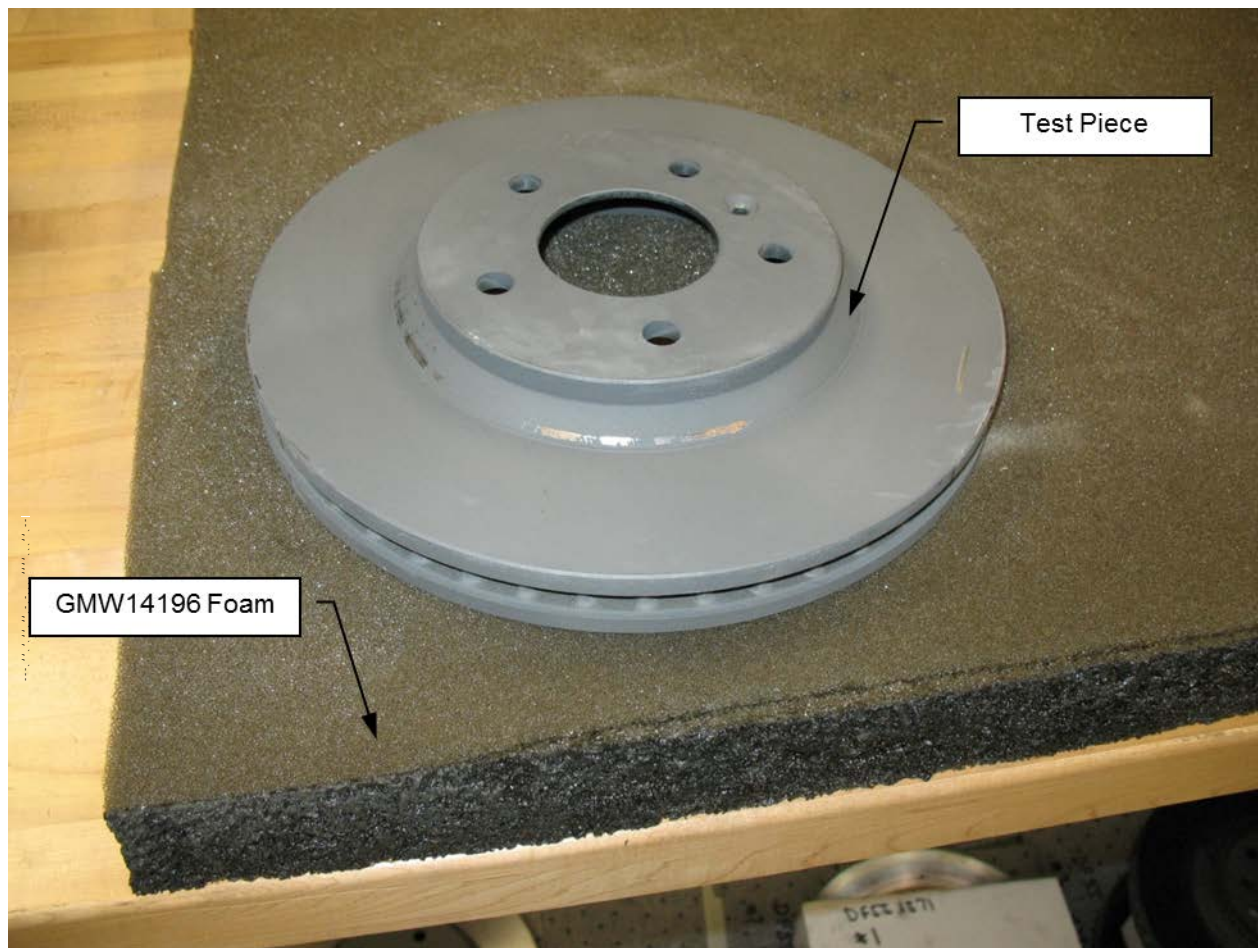


Figure A1: GMW14196 Foam Used to Support Brake Components in Free-Free Condition

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Table A1: Equipment Specifications

Equipment	Specifications
Small Impact Hammer	Sensitivity: ≥ 20 mV/N to 25 mV/N Frequency Range: 1 Hz to 20 000 Hz (-10 dB) Maximum Range: ± 220 N
Medium Impact Hammer	Sensitivity: ≥ 10 to 12 mV/N Frequency Range: 1 Hz to 9500 Hz (-10 dB) Maximum Range: ± 440 N
Shaker(s)	100 N to 200 N maximum (sine) rating Low armature mass and support stiffness
Uniaxial Accelerometers	Mass: < 2.0 g Sensitivity: ≥ 1 mV/(m/s ²) Frequency Range: 1 Hz to 20 000 Hz (± 3 dB) Maximum Range: 500 m/s ² Resolution: > 0.0005 m/s ² Transverse Sensitivity and Non-Linearity: $\leq 5\%$ and $\leq 1\%$
Triaxial Accelerometers	Mass: < 5.0 g Sensitivity: ≥ 1 mV/(m/s ²) Frequency Range: 1 Hz to 20 000 Hz (± 3 dB) Maximum Range: 500 m/s ² Resolution: > 0.0005 m/s ² Transverse Sensitivity and Non-Linearity: $\leq 5\%$ and $\leq 1\%$
Laser Doppler Vibrometer	Sensitivity: 1 mm/s/V to 1000 mm/s/V Frequency Range: 1 Hz to 20 000 Hz (@ > 5 mm/s/V) Maximum Range: 70 kg to 1600 kg Resolution: 0.3 μ m to 10 μ m Non-Linearity: $\leq 2.5\%$
Force Transducer(s)	Sensitivity: > 10 mV/N Maximum Range: 450 N

Note: @ = at

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