



Tire Force Transmissibility and Wheel Lateral Stiffness Evaluation Procedure

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.

Note: The Transducer Calibration Master Test Procedure, GMW14172 and the Hand Held Force Input Frequency Response Function (FRF) Acquisition Master Test Procedure, GMW14181, shall be referenced for more detailed information corresponding to the procedure contained herein.

1.1 Purpose. Define the process for obtaining the tire and wheel force transmissibility and wheel lateral stiffness. These measurements are used to compare tire force transmissibility and wheel lateral stiffness to the specifications.

1.2 Applicability. The test procedure is appropriate to use for all passenger cars, vans and small bus tire wheel systems.

1.3 Remarks. The tire and wheel force transmissibility and wheel lateral stiffness are factors in structure borne road noise performance.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14172 GMW14181

2.3 Additional References.

- Brüel & Kjær (B&K) North America Incorporated, Norcross, Georgia
- Fluke Precision Measurement Limited, San Diego, California
- OROS Incorporated, Dulles, Virginia
- PCB Piezotronics, Incorporated, Depew, New York
- Subsystem Technical Specifications (SSTS)

3 Resources

3.1 Facilities. A test room or an area which is free of extraneous vibration (see GMW14181).

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.

3.2.1 Test Equipment. Two (2) measuring methods can be used to measure the tire and wheel transmissibility under free-free condition. Excitation with impact hammer or hand held shaker. The required equipment for both

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methods is different, however, the measurement results are comparable. Equivalent measurement equipment may be used in place of the suggested equipment.

3.2.1.1 Equipment (Excitation with Impact Hammer).

3.2.1.1.1 One (1) Four (4) channel Fast Fourier Transform (FFT) analyzer (e.g., OROS 25, available through OROS Incorporated).

3.2.1.1.2 One (1) impact hammer with force transducer and nylon hammer tip (e.g., PCB small impact hammer, available through PCB Piezotronics Incorporated).

3.2.1.1.3 One (1) triaxial accelerometer for vertical and lateral acceleration on the tire patch (i.e., PCB 353 B33 ICP, available through PCB Piezotronics Incorporated).

Note: Integrated Circuit Piezoelectric (ICP) is the most commonly used accelerometer technology.

3.2.1.1.4 Two (2) single axis accelerometers for acceleration on each side of wheel center (e.g., PCB 353 B65 ICP, available through PCB Piezotronics Incorporated).

3.2.1.1.5 Accelerometer Calibrator.

3.2.1.1.6 Calibration Mass.

Note: Refer to GMW14172 for more calibration details.

3.2.1.2 Equipment (Excitation with Hand Held Shaker).

3.2.1.2.1 One (1), Four (4) channel FFT analyzer (e.g., OROS 25, available through OROS Incorporated).

3.2.1.2.2 One (1) waveform generator (e.g., WAVETEK Model 395, available through Fluke Precision Measurement Limited).

3.2.1.2.3 Hand held shaker with force transducer (e.g., Shaker: B&K Type 4819 and Force Transducer B&K B200 185 524 60, available through Brüel & Kjær North America Incorporated).

3.2.1.2.4 Power amplifier (e.g., B&K 2706, available through Brüel & Kjær North America Incorporated).

3.2.1.2.5 One (1) triaxial accelerometer for vertical and lateral acceleration on the tire patch (e.g., PCB 354 B33 ICP, available through PCB Piezotronics Incorporated).

3.2.1.2.6 Two (2) single axis accelerometers for acceleration on each side of wheel center (e.g., PCB 353 B65 ICP, available through PCB Piezotronics Incorporated).

3.2.1.2.7 Accelerometer Calibrator.

3.2.1.2.8 Calibration Mass.

Note: Refer to GMW14172 for more calibration details.

Note: Alternative equipment by other manufacturers are useable.

3.3 Test Vehicle/Test Piece. Tire and wheel.

3.4 Test Time.

Calendar time: 0.5 days

Test hours: 2 hours

Coordination hours: 2 hours

3.5 Test Required Information. Not applicable.

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

4 Procedure

4.1 Preparation.

4.1.1 Check tire pressure and insure that the pressure is set to design intent level. Weigh the tire/wheel assembly or wheel only (bare wheel) to obtain the mass of the test object (see Appendix A, Figure A1).

4.1.2 The test tire and wheel will be hung from elastic cords to allow the free-free condition in the direction of excitation. The rigid body mode of the tire and wheel shall be below 3 Hz. The test tire and wheel shall be

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secured appropriately to the elastic cords and the loading limits of the cords shall not be exceeded (see Appendix A, Figure A1 for an example of a tire and wheel boundary condition).

4.1.3 Two (2) single axis accelerometers (M1 and M2) shall be attached with **hot glue** on each side of the wheel center in the direction of excitation (see Appendix A, Figure A2 for single axis accelerometers (M1 and M2) placement). These two (2) single accelerometers shall be positioned equidistant from the hub center and **at the bolt circle diameter (BCD) circumference** (referring to the red circle in Appendix A, Figure A2). The straight line between the two (2) accelerometers shall go through the hub center. A triaxial accelerometer (M3) shall be positioned along this straight line, on top of the tire. Typically, the straight line is oriented to be a vertical line for an easy measurement. Accelerometer directions shall be positioned in accordance with either Z or Y force transmissibility measurement directions.

4.1.4 The triaxial accelerometer (M3) will be affixed directly on the tire tread with hot glue when the force transmissibility from a tire to a wheel hub needs to be measured. Only the vertical and lateral directions will be used (see Appendix A, Figure A3 for triaxial accelerometer (M3) placement). This accelerometer (M3) shall not be mounted if only the stiffness of a tire/wheel assembly or a bare wheel is required to be measured.

4.1.5 For accelerometer and force transducer calibrations, see GMW14172.

4.2 Conditions.

4.2.1 Environmental Conditions.

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 Analyzer Acquisition Parameters.

- Channel 1 (CH1): Force signal Impact Hammer ICP coupled auto range.
- Channel 2 (CH2): Acceleration signal tire tread (M3) ICP coupled auto range.
- Channel 3 (CH3): Acceleration signal wheel below center (M1) ICP coupled auto range.
- Channel 4 (CH4): Acceleration signal wheel above center (M2) ICP coupled auto range.
- Trigger: 10% slope channel and approximately 0.03 seconds pre-trigger.
- Average: Six (6) averages (minimum).
- Overlap: None.
- Window: Rectangular (uniform).
- Maximum frequency: 2048 Hz.
- Minimum frequency resolution: 1 Hz or 0.25 Hz preferable for the tire and wheel system (see 5.1.4.1). For wheel only measurements, 0.125 Hz frequency resolution is recommended in the case that a wheel has little damping to stop ringing.
- Overload detection: Enabled.

4.3.1.2 The excitation will be made using an impact hammer.

4.3.1.2.1 For the following locational descriptions, refer to Appendix A, Figure A2. For a stiff hub such as an aluminum wheel hub, two (2) lateral and two (2) vertical impacts, both above and below the wheel center will be made. Two (2) single axis accelerometers are positioned/mounted laterally at M1 and M2 as illustrated. Lateral impact position P1 is located 90 degrees perpendicular to the straight line between accelerometers M1 and M2. Lateral impact position P2 is located adjacent to accelerometer M2. ***Lateral impact locations and lateral accelerometer positions shall be aligned with the circumference of a BCD. If a mounting hole or a non-flat surface occurs, the impact positions and accelerometers shall be as close as possible to the BCD on adjacent flat locations.*** For vertical transmissibility, mount the accelerometers vertically at M1 and M2. Impact positions V1 and V2 are performed vertically, respectively at the locations on the pilot hole edges along the straight line between M1 and M2. Therefore, four (4) lateral Drive Point FRFs and four (4) vertical Drive Point FRFs are generated around the hub. Two Transfer FRFs between M3 and M1 (or M2) are also measured. Refer to 4.3.1.6 for notations and 5.1 for calculations.

4.3.1.2.2 For the following locational descriptions, refer to Appendix A, Figure A4. For a less rigid or shallow hub such as a **steel wheel** hub, ***eight (8) lateral impacts will be made radially along the circumference of a***

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BCD. Two (2) single axis accelerometers are positioned/mounted laterally at M1 and M5 as illustrated. Impacts are made at positions P1 through P8, spaced 45 degrees apart and at BCD or as close as possible to BCD. Therefore, 16 Drive Point FRFs are generated around the hub and 8 Transfer FRFs between M3 and P1 to P8 are also measured. Refer to 4.3.1.6 for notations and 5.1 for calculations.

4.3.1.3 Measurement functions:

- a. FFT spectrum force input
- b. Transfer FRFs
- c. Driving point FRF
- d. Coherence

4.3.1.4 Start the analyzer or commercial measurement system.

4.3.1.5 Measurement will be stopped automatically after six (6) averages.

4.3.1.6 Store the measured data on hard disk.

Two-point excitation for both Y and Z directions:

- a. Driving point FRFs (H_{11} , H_{21} , H_{12} , H_{22})
- b. Transfer FRFs (H_{31} , H_{32})

Where: The first subscript position is Response from an accelerometer; M1, M2 or M3 and the second subscript position is Force (impact) at a location; P1, P2, V1 or V2, e.g., H_{21} is an FRF response from accelerometer M2 with an impact from either P1 or V1. See Appendix A, Figures A2 and A3.

Eight-point excitation for a shallow hub (such as **steel wheel**) only in Y direction:

- a. Driving point FRFs (H_{11} , H_{12} , H_{13} , H_{14} , H_{15} , H_{16} , H_{17} , H_{18} and H_{51} , H_{52} , H_{53} , H_{54} , H_{55} , H_{56} , H_{57} , H_{58})
- b. Transfer FRFs (H_{91} , H_{92} , H_{93} , H_{94} , H_{95} , H_{96} , H_{97} , H_{98})

Where: The first subscript position is Response from an accelerometer; "1" = M1, "5" = M2, "9" = M3 and the second subscript position is Force (impact) at a location; P1 through P8, e.g., H_{96} is an FRF response from accelerometer M3 with an impact from P6. See Appendix A, Figures A3 and A4.

4.3.2 Hand Held Shaker Excitation

4.3.2.1 Select on waveform generator a sine signal (frequency 10 Hz to 2024 Hz). The frequency range should be continuously driven in UP/DOWN mode. The time duration for each run should be 15 s. Store the setup for the waveform generator attitudes.

4.3.2.2 Select at the power amplified, a force of ± 1 N.

4.3.2.3 Select the right sensitivity of the force transducer at the charge amplifier (see force transducer documentation).

4.3.2.4 Analyzer Acquisition Parameters.

- CH1: Force signal hand held shaker Alternating Current (AC) coupled (10 Hz high pass filter) auto range.
- CH2: Acceleration signal tire tread (M3) ICP coupled auto range.
- CH3: Acceleration signal wheel below center (M1) ICP coupled auto range.
- CH4: Acceleration signal wheel above center (M2) ICP coupled auto range.
- Average: 100 averages (linear).
- Overlap: 50%, Hanning windows.
- Maximum frequency: 500 Hz.
- Resolution: 1 Hz (0.25 Hz preferred), 0.125 Hz recommended for wheel only in the case that a wheel has little damping to stop ringing.
- Overload detection: Enabled.

4.3.2.5 The excitation will be made with the hand held shaker both above and below the wheel center in the vertical direction.

4.3.2.6 Display the following signals during data acquisition:

- a. All input time signals
- b. Transfer FRFs
- c. Driving point FRF

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