



## **Fixture-Based Tire/Wheel Force and Moment Transmissibility 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.

**Note:** As an alternative, Tire Force Transmissibility and Wheel Lateral Stiffness Evaluation Procedure, GMW14876, can be used to evaluate the tire/wheel force transmissibility only in the tire radial and lateral directions under free-free boundary conditions without involving any moment measurements and associated load cells and fixtures. This procedure is intended to extend GMW14876 to cover both force and moment measurements for either a tire/wheel assembly or a wheel alone.

**1.1 Purpose.** Define the process for obtaining the tire/wheel assembly or wheel alone force and moment transmissibility. These measurements are used to compare the transmissibility values to the specifications.

**1.2 Applicability.** The test procedure is appropriate to use for all passenger cars, vans and small bus tire/wheel assemblies or a wheel alone.

**1.3 Remarks.** The tire/wheel assembly or wheel alone force and moment transmissibility specifications are important 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

GMW14876

#### **2.3 Additional References.**

- Brüel & Kjær (B&K) North America Incorporated, Norcross, Georgia
- Fluke Precision Measurement Limited, San Diego, California
- Kistler Instrument Corporation, Amherst, New York
- LMS International, A Siemens Business, Leuven, Belgium
- OROS Incorporated, Dulles, Virginia
- PCB Piezotronics, Incorporated, Depew, New York
- Subsystem Technical Specification (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.

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**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 Method.** Two (2) excitation methods (either an impact hammer or a hand/stand held shaker) can be used to measure the tire/wheel assembly or wheel alone transmissibility under a fixed condition. The required equipment for both methods is different, however, the measurement results are comparable. Equivalent measurement equipment may be used in place of the suggested equipment. The remainder of the equipment, including load cell and associated fixtures, is the same.

**3.2.2 Test Load Cell, Fixture and Base.** The transmitted reactive forces and moments at the wheel center are measured by a load cell via a mounting fixture and an adapter, as shown in Appendix A, Figures A1 thru A3. The forces and moments shall be measured in the grounded or "fixed" condition so a very large mass or solid structure, called a "base", shall be applied. The base, made of an aluminum cylinder and a heavy solid iron hexahedron shall weigh more than 2500 kg. The base is supported by four (4) air springs which should generate rigid-body modes less than 5 Hz. If no air springs are applied, the base can be a grounded solid structure and is recommended to have a mass of 10 000 kg or higher.

#### 3.2.2.1 Equipment (Excitation with Impact Hammer).

**3.2.2.1.1** One (1) four (4) channel Fast Fourier Transform (FFT) analyzer (i.e., OROS 25, available through OROS Incorporated) or one (1) commercial measurement system (i.e., LMS Test.Lab, available through LMS International).

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

**Note:** Integrated Circuit Piezotronics (ICP) is the most commonly used force gauge technology.

**3.2.2.1.3** One (1) load cell for three (3) translation forces ( $F_x$ ,  $F_y$  and  $F_z$ ) and two (2) rotation moments ( $M_x$  and  $M_z$ ) (i.e., Kistler K16460, available through Kistler Instrument Corporation). Refer to Appendix A, Figure A3 for coordinates.

**3.2.2.1.4** Calibration mass.

**Note:** Refer to GMW14172 for more calibration details.

#### 3.2.2.2 Equipment (Excitation with Hand Held Shaker).

**3.2.2.2.1** One (1) Four (4) channel FFT analyzer (i.e., OROS 25, available through OROS Incorporated) or one (1) commercial measurement system (i.e., LMS Test.Lab, available through LMS International).

**3.2.2.2.2** One (1) waveform generator (i.e., WAVETEK Model 395, available through Fluke Precision Measurement Limited).

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

**3.2.2.2.4** Power amplifier (i.e., B&K 2706, available through Brüel & Kjær North America Incorporated).

**3.2.2.2.5** One (1) load cell for three (3) translation forces ( $F_x$ ,  $F_y$  and  $F_z$ ) and two (2) rotation moments ( $M_x$  and  $M_z$ ) (i.e., Kistler K16460, available through Kistler Instrument Corporation). Refer to Appendix A, Figure A3 for coordinates.

**3.2.2.2.6** Calibration mass.

**Note:** Refer to GMW14172 for more calibration details.

**Note:** Alternative equipment by other manufacturers is usable.

**3.3 Test Vehicle/Test Piece.** Tire/wheel assembly or a wheel alone.

### 3.4 Test Time.

Calendar time: 0.25 day

Test hours: 0.5 to 1 hour

Coordination hours: 1 hour

**3.5 Test Required Information.** Not applicable.

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**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 ensure 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.

**4.1.2** The test tire/wheel assembly or the bare wheel will be installed into the mounting fixture, see Appendix A, Figure A1, which has five (5) sliding blocks with bolts to position to any 5-bolt pattern wheel. The fixture can fit any size bolt diameter wheel. Similarly, 4-bolt, 6-bolt and 8-bolt pattern fixtures for various wheel bolt patterns may be required.

**4.1.3** Two (2) input forces can be applied by either an impact hammer or a shaker along the Z direction (tire radial) and the Y direction (tire side). Refer to Appendix A, Figures A3 thru A5. The force  $F_z$  along Z direction is applied into the tire crown center, normal to the tire surface; and the force  $F_y$  along Y direction is applied into the tire crown edge, as shown in Appendix A, Figure A4. Similarly, the force can be applied to the bare wheel rim center  $F^w_z$  and the wheel flange  $F^w_y$  as drawn in Appendix A, Figure A5.

**4.1.4** One (1) load cell shall be installed beneath the mounted wheel to measure the transmitted forces ( $F_x$ ,  $F_y$  and  $F_z$ ) and moments ( $M_x$  and  $M_z$ ) at the wheel center shown in Appendix A, Figure A1. The force and moment directions and associated coordinates are defined in Appendix A, Figure A2.

**4.1.5** For 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 Impact Hammer Excitation.

##### 4.3.1.1 Analyzer Acquisition Parameters.

- Channel 1 (CH1): Force signal  $F_z$  or  $F_y$  impact hammer ICP coupled auto range
- Channel 2 (CH2): Force  $F_x$  Voltage Alternating Current (AC) coupled auto range
- Channel 3 (CH3): Force  $F_y$  Voltage AC coupled auto range
- Channel 4 (CH4): Force  $F_z$  Voltage AC coupled auto range
- Channel 5 (CH5): Force  $M_x$  Voltage AC coupled auto range
- Channel 6 (CH6): Force  $M_z$  Voltage AC coupled auto range
- Trigger: 10% slope channel and approximately 0.03 s pre-trigger
- Average: Six (6) averages (minimum)
- Overlap: None
- Window: Rectangular (uniform)
- Maximum frequency: 1024 Hz
- Minimum frequency resolution: 1 Hz preferable for the tire/wheel assembly (see Appendix A, Figure A1) and the bare wheel (see Appendix A, Figure A2). A frequency resolution of 0.25 Hz is recommended if a bare wheel has little damping to stop ringing.
- Overload detection: Enabled
- FRF Function:  $H1$

**4.3.1.2** The excitation will be made using an impact hammer along Z direction or Y direction as defined either in Appendix A, Figure A4 for the tire/wheel assembly or Appendix A, Figure A5 for the bare wheel.

##### 4.3.1.3 Measurement functions:

- a. FFT Spectrum force input

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- b. Transfer FRFs (the ratio of transmitted force or moment over input force)
- c. 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.

The measured transfer FRFs are the directly measured force or moment transmissibility as follows:

Three (3) translation forces along Z direction:

$$\frac{F_x}{F_z^t}, \quad \frac{F_y}{F_z^t}, \quad \frac{F_z}{F_z^t}$$

Three (3) translation forces along Y direction:

$$\frac{F_x}{F_y^t}, \quad \frac{F_y}{F_y^t}, \quad \frac{F_z}{F_y^t}$$

Two (2) rotation moments along Z direction:

$$\frac{M_x}{F_z^t}, \quad \frac{M_z}{F_z^t}$$

Two (2) rotation moments along Y direction:

$$\frac{M_x}{F_y^t}, \quad \frac{M_z}{F_y^t}$$

Note that the preceding formulas are derived by assuming that the forces are applied to the tire for a tire/wheel assembly and the similar formulas can be derived when the forces are applied to a bare wheel by changing the superscript "t" to "w" in the denominator.

#### **4.3.2 Hand Held Shaker Excitation.**

**4.3.2.1** Select on waveform generator, a sine signal (frequency 10 Hz to 512 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 amplifier, a force of  $\pm 1$  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.**

- Channel 1 (CH1): Force signal  $F_z$  or  $F_y$  shaker AC coupled (10 Hz high pass filter) auto range
- Channel 2 (CH2): Force  $F_x$  Voltage AC coupled auto range
- Channel 3 (CH3): Force  $F_y$  Voltage AC coupled auto range
- Channel 4 (CH4): Force  $F_z$  Voltage AC coupled auto range
- Channel 5 (CH5): Force  $M_x$  Voltage AC coupled auto range
- Channel 6 (CH6): Force  $M_z$  Voltage AC coupled auto range
- Average: 100 averages (linear)
- Overlap: 50%, Hanning windows
- Window: Rectangular (uniform)
- Maximum frequency: 512 Hz
- Resolution: 1 Hz. If a bare wheel has little damping to stop ringing, 0.25 Hz is recommended.
- Overload detection: Enabled
- FRF Function: *H1*

**4.3.2.5** The excitation will be made with the hand/stand held shaker along Z direction or Y direction as defined in Appendix A, Figure A3. A hand held shaker is shown in Appendix A, Figure A6.

**4.3.2.6** Display the following signals during data acquisition:

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