



Spindle - Acoustic Sensitivity and Mobility Level Evaluation Procedure

1 Introduction

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

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. Define the process for obtaining the acoustic sensitivity level and the associated drive point mobility level at each spindle in three (3) translational orthogonal degrees of freedom (x, y, and z) and in two (2) rotational orthogonal degrees of freedom ($\hat{x}$ and $\hat{z}$). The tire/wheel spindle moment (torque) inputs are measured in this procedure.

1.2 Applicability. This test procedure is appropriate to use for all passenger car and truck systems.

1.3 Remarks. The acoustic sensitivity and mobility of the spindle attachment is a factor in overall road noise performance of a vehicle.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW8460 GMW14172 GMW14181

2.3 Additional References. None.

3 Resources

3.1 Facilities. A full or hemi anechoic test facility, which is free of extraneous noise and vibration (per 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.

- Data Acquisition System (DAS)
- Microphone(s)
- 10 mV/(m/s²) accelerometer (weight less than 6×10^{-3} kg)
- Small or medium impact hammer with tip capable of providing uniform force input out to 800 Hz, or
- Hand held shaker and force transducer
- Transducer cabling and signal conditioning

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December 2016

Page 1 of 9

Note: For data acquisition 20 Hz to 800 Hz, multiple hammers may be required due to signal to noise issues. See GMW14181 for low/high frequency acoustic sensitivity data acquisition suggestions.

3.3 Test Vehicle/Test Piece. The test requires the complete vehicle with tire/wheel system removed. The vehicle shall be supported via the suspension to simulate the suspension-loaded condition, on the knuckle or as close to the strut/shock knuckle as possible. All suspension parts must be oriented similar to how they are oriented during normal vehicle operation. Duplicating suspension orientation and alignment will ensure proper loading of the isolators. Vehicle shall be structurally isolated from the supporting structure via rubber isolators.

3.4 Test Time.

Calendar time: 1 day

Test time: 6 hours

Coordination time: 1 hour

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Wholly contained in GMW14181.

4 Procedure

4.1 Preparation.

4.1.1 Vehicles with manual transmissions shall be placed in neutral and automatic transmission equipped vehicles shall be placed in park. The parking brake shall not be engaged to enable rotation of the rotors for measurements of spindle moments.

4.1.2 Three (3) tire/wheel fasteners (lug nuts) shall be used and manufacturer's recommended torque specification shall be followed to solidly secure the rotor to the spindle bearing. If the fasteners are too long, spacers such as washers may need to be added. Refer to Appendix A, Figure A1.

4.1.3 Ensure the windows are closed, sunroof/sunshade is closed and all swing metal is closed (e.g., trunk, doors, hood, etc.) Mount the body on four (4) rubber isolators (isopad blocks, 300 N/mm rate) to approximate a free-free mounting boundary condition. The rigid body modes of the vehicle on the isolators should be ten (10) times less than the lowest frequency of interest. Normally the rigid body modes of the vehicle should be less than 5 Hz with the suspension loaded on isopad blocks. Isolator rates may be stiffer for heavy vehicles such as a full size Sport Utility Vehicle (SUV). See Appendix B, Figures B1 and B2 for examples of suspension loaded on isopad blocks.

4.2 Conditions. Wholly contained in GMW14181.

4.2.1 Environmental Conditions. Wholly contained in 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 up a data acquisition system to acquire acoustic sensitivity FRF in the units of Pascal per Newton [Pa/N] and accelerance FRF in the units of meter per second squared per Newton [(m/s²)/N] both from 0 Hz to 1024 Hz with 1 Hz resolution.

4.3.2 Instrument the interior of the vehicle with microphones per GMW8460, GMNA Deviations. In addition, place a microphone in the driver seat using the same specifications listed in GMW8460 for the front passenger microphone location. Use A-weighting functions for the microphones to optimize the signal to noise ratio at high frequency (250 Hz and greater).

4.3.3 Using an impact hammer or hand held shaker and force transducer, apply a force at the spindle attachment in the same direction the accelerometer is mounted. See Appendix C, Figure C1. Continue measuring FRFs for all three (3) orthogonal directions at all of the spindle attachment points. Refer to GMW14181 for GM standard vehicle coordinate directions and appropriate accelerometer mounting adhesives.

- Instrument each spindle interface with an accelerometer, which will be used for both Z and X directions. See Appendix C, Figures C1 and C2. Impact Z direction on top of the bearing hub pilot, which inserts into the wheel hub and measure the acceleration from the bottom of the pilot. It is usually possible to turn the rotor 90 degrees clockwise without remounting the accelerometer and impact X direction on one side and measure the

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December 2016

Page 2 of 9



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acceleration on the opposite side of the pilot. The driver point accelerance (acceleration over force) and pressure over force spindle sensitivity can be measured directly.

- As for the Y direction, refer to Appendix C, Figures C3 and C4, mount two (2) single accelerometers on the top and bottom of the pilot, impact both spots so one measures four (4) FRFs, H_{y11} , H_{y21} , H_{y12} , and H_{y22} . Here "1" denotes the top impact spot, "2" denotes the bottom impact spot, and "y" stands for the y-direction impact. These impact locations yield the data required for the y-axis and rotation about x-axis calculations. Record the distance "d" between two (2) accelerometer centers. Rotate the rotor 90 degrees clockwise once again, repeat the preceding process, and measure four (4) FRFs, H_{y33} , H_{y43} , H_{y34} , and H_{y44} . Here "3" denotes the left side impact spot and "4" denotes the right side. These impact locations yield the data required for the y-axis and moment about z-axis calculations. Two (2) accelerometers allow for measurement of moment or torque inputs.
- Y-direction driver point accelerance (the pilot center acceleration vs. the center force) can be mathematically solved by Equation 4.1:

$$H_y = \frac{1}{8}(H_{y11} + H_{y21} + H_{y12} + H_{y22} + H_{y33} + H_{y43} + H_{y34} + H_{y44}) \quad (\text{Equation 4.1})$$

Note: When dealing with complex numbers adding and subtracting (used in the following), the user needs to perform the operation on the real parts and imaginary parts separately to calculate the final amplitude or decibel (dB) values of H_y

- Y-direction pressure vs. the pilot center force spindle sensitivity can be written as (see Equation 4.2):

$$\left(\frac{P}{F}\right)_y = \frac{1}{4}\left[\left(\frac{P}{F}\right)_{y1} + \left(\frac{P}{F}\right)_{y2} + \left(\frac{P}{F}\right)_{y3} + \left(\frac{P}{F}\right)_{y4}\right] \quad (\text{Equation 4.2})$$

Where:

$y1$ thru $y4$ denote the Y impact positions as defined previously.

- $\hat{X}$ -direction driver point angular accelerance (angular acceleration around the pilot center vs. moment) can be mathematically solved by Equation 4.3:

$$\hat{H}_x = \frac{1}{d^2}(H_{y11} + H_{y22} - H_{y21} - H_{y12}) \quad (\text{Equation 4.3})$$

- $\hat{X}$ -direction pressure vs. moment (along global X axis) spindle sensitivity can be written as (see Equation 4.4):

$$\left(\frac{P}{F}\right)_x = \frac{1}{d}\left[\left(\frac{P}{F}\right)_{y2} - \left(\frac{P}{F}\right)_{y1}\right] \quad (\text{Equation 4.4})$$

- Similarly, $\hat{Z}$ -direction driver point angular accelerance (angular acceleration vs. moment) can be written as (see Equation 4.5):

$$\hat{H}_z = \frac{1}{d^2}(H_{y33} + H_{y44} - H_{y43} - H_{y34}) \quad (\text{Equation 4.5})$$

- $\hat{Z}$ -direction pressure vs. moment (along global Z axis) spindle sensitivity can be written as (see Equation 4.6):

$$\left(\frac{P}{F}\right)_z = \frac{1}{d}\left[\left(\frac{P}{F}\right)_{y3} - \left(\frac{P}{F}\right)_{y4}\right] \quad (\text{Equation 4.6})$$

4.3.4 For each measurement, measure spindle driving point accelerance and acoustic sensitivity, check coherence and verify levels. Upon measurement completion, store the accelerance FRFs, acoustic sensitivity FRFs, coherence and force autopower spectrum.

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December 2016

Page 3 of 9



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