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| GM | WORLDWIDE ENGINEERING STANDARDS | Test Procedure | GMW15120 |

# Tire Highway Speed Uniformity

## 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 document provides details for testing passenger car and light truck tires for Highway Speed Uniformity (HSU).

**1.2 Applicability.** This procedure applies to the testing of tires on an HSU machine at zero slip angle and zero inclination angle.

**1.3 Remarks.** HSU data is used in such applications as vehicle sensitivity tests, auditing assembly plant tire/wheel assemblies, analyzing tires/wheel assemblies from complaint vehicles, and auditing tire production variation. The HSU parameters of interest include primarily the first four (4) harmonics, magnitudes and phases.

## 2 References

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

**2.1 External Standards/Specifications.**

SAE J4332

**2.2 GM Standards/Specifications.**

GMW16590

## 3 Resources

**3.1 Facilities.**

**3.2 Equipment.** All details associated with the test apparatus are included in SAE J4332.

**3.2.1** The roadwheel should be covered with either medium grit 3M Safety Walk or 80 grit 3M type. The surface should be replaced at routine intervals to eliminate it as a source of testing variability**.**

**3.3 Test Vehicle/Test Piece**. A tire/wheel assembly is required to run an HSU test. The wheel is either the wheel from the assembly as it came from a complaint vehicle, or in the case of an audit of multiple tires, a set of production or test wheels may be used to obtain the HSU results for the audit tires (tire only). For audit testing, only the tire contribution is of interest. Therefore, the tester must implement a process to limit the wheel contribution to the HSU results to be less than 15 N for each parameter. The test requester will specify the width and rim flange of the wheel.

**3.4 Test Time.**

| | |
|---|---|
| Calendar time: | 1 day |
| Test time: | 1 hour |
| Coordination time: | 1 hour |

**3.5 Test Required Information**. Required information includes tire size, construction number, load rating, service description, and wheel width. Additional information required may vary by test site.

**3.6 Personnel/Skills**. Test operator should have adequate training and be familiar with the local operator's procedure.



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# 4 Procedure

## 4.1 Preparation.

**4.1.1** Tires must be mounted on the appropriate wheels. See 3.3.

**4.1.2** All tires must be mounted in the proper orientation with respect to the front face of the test wheels. White wall tires must be mounted white wall out with respect to the front face of the wheels. Black wall tires must be mounted with the cosmetic or intended outboard sidewall mounted out with respect to the front face of the test wheels.

**4.1.3** Assemblies or individual tires and wheels should be at ambient room temperature (24.0 °C ± 3.0 °C) for a minimum of 2 h before an HSU test.

**4.1.4** The assembly should always be mounted on the machine in the standard position, in which the valve stem is aligned with the zero mark on the spindle. If this is not possible because the spindle studs do not line up with the bolt holes, the assembly is rotated clockwise (CW) until the studs and bolt holes do line up. The angle through which the assembly was rotated is then used to correct the phase angles of the Fast Fourier Transform (FFT).

**4.1.5** Minimizing the radial runout is very important to minimize mounting contribution to uniformity. Follow local mounting instructions using expandable collets, and other mounting hardware in order to optimize the centering of the tire/wheel mounting to the machine.

## 4.2 Conditions.

**4.2.1 Environmental Conditions.** Ambient temperature must be kept at 24.0 °C ± 3.0 °C. A method for monitoring ambient temperature must be in place.

**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.

**4.2.2.1 Load and Pressure.** Tires must be tested at standard test conditions unless otherwise specified by the Tire Test Request. Standard test conditions are defined in Table 1.

**Table 1: Calculation of Standard HSU Test Conditions**

| Tire Type | Load Range | Test Load | Test Pressure |
|---|---|---|---|
| Passenger Car | All | 70% of maximum load | 210 kPa |
| Light Truck or Commercial | All | 70% of load capacity at 350 kPa | 350 kPa |

**4.2.2.2 Speed.** The typical test speeds used to evaluate HSU is a range of 8 speeds from 80 km/h through 150 km/h in 10 km/h increments, in both CW and counterclockwise (CCW) directions. However, a single speed, 120 km/h, may be used to satisfy certain production audit requirement. Other speeds, not listed here, may also be requested depending upon the specific data requirements.

## 4.3 Instructions.

### 4.3.1 Highway Speed Uniformity.

**4.3.1.1 Warmup**. The first step is to warmup the tire. The tire warmup is performed at the test load and pressure and 120 km/h in the CW direction for 20 minutes. If a tire is put through multiple tests that occur within 5 minutes of each other, only the first test of the tire requires a warmup.

**4.3.1.2 Data Collection**. The set points (load and speed combinations) are run in this order.

**4.3.1.2.1** The road wheel is first running in the CW direction.

**4.3.1.2.2** The speed of the first test condition is set.

**4.3.1.2.3** The load of the first test condition is set.

**4.3.1.2.4** The composite data is then acquired once the tire has reached a steady state condition. Eight (8) revolutions of data are acquired.



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**4.3.1.2.5** Repeat 4.3.1.2.2 through 4.3.1.2.4 for all CW speed conditions.

**4.3.1.2.6** The unbalanced data for the CW direction is now collected.

**4.3.1.2.6.1** Accelerate the roadwheel to a speed incrementally higher than the highest test speed.

**4.3.1.2.6.2** Move the test wheel away from the roadwheel so that it is free spinning.

**4.3.1.2.6.3** As the tire is decelerating, collect unbalanced data at each of the test speed conditions. Eight (8) revolutions of data are acquired for the unbalanced data for each test speed condition.

**4.3.1.2.6.4** The tire is reloaded to the roadwheel at the last test speed. Caution should be taken not to reload tire when large speed differences exist**.**

**4.3.1.2.7** Change direction of the roadwheel to CCW and repeat 4.3.1.2.2 through 4.3.1.2.6 for all speed conditions in ascending order**.**

**4.3.1.3 Analysis.** Detailed analysis is described in 5.1. In summary, the data is analyzed in three (3) ways using FFT. The composite data is analyzed by itself, the unbalance data is analyzed by itself, and the difference of the composite and unbalance, called the assembly data, is analyzed. The machine contribution can be subtracted out of both the composite and assembly data if desired.

**4.3.2 Machine Contribution.**

**4.3.2.1** Machine contributions can be calculated for every harmonic of each parameter at any speed and load. However, typically only Radial first Harmonic (R1H) and fore/aft First Harmonic (F1H) are subtracted out of the composite and assembly data. These steps detail the procedure.

**4.3.2.2** Run a standard warmup for the assembly in its standard position on the machine. Refer to 4.3.1.1 for the warmup procedure.

**4.3.2.3** Acquire the composite data at all necessary loads and speeds (4.3.1.2). It is not necessary to acquire the unbalance data.

**4.3.2.4** Remount the assembly on the machine, rotating the assembly one bolt hole CW relative to the standard position on the spindle.

**4.3.2.5** Repeat 4.3.2.3.

**4.3.2.6** Repeat 4.3.2.3 and 4.3.2.4 for all other bolt holes of the assembly.

**4.3.2.7** In the cases of machines where the wheel is not dismounted from the machine to mount the tire, the process would be done by rotating the tire with respect to the wheel in a set of equal angle rotations, making up one full rotation.

## 5 Data

### 5.1 Calculations.

### 5.1.1 Highway Speed Uniformity.

**5.1.1.1** All eight (8) revolutions of the acquired data are averaged and adjusted for crosstalk: Fx(i), Fy(i), Fz(i), MX(i) and MZ(i).

**5.1.1.2** The magnitudes and phase angles of radial, fore/aft and lateral forces, as well as overturning moment and aligning torque for each harmonic are calculated based on these formulations, typically through a FFT of the data.

$$Fz(i) = \sum_{j=1}^{n} RjH * COS(\frac{2*PI}{j*T} * \frac{i}{m} + RjP)$$

**Where:**

- Fz(i) = measured as an eight (8) revolutions averaged radial force in SAE International (SAE) coordinate system at each sample points in one (1) revolution.
- I *i* =variable index of sample points i =1, 2, m.
- M = number of sample points per revolution, such as 4096.
- j = variable index of harmonic j = 1,2,…,n, where n is number of the last harmonic, such as 16, 32.



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- $R_jH$ = the decomposed magnitude (Newtons) of the radial force at harmonic *j* or frequency of 1/(j*T).
- $R_jP$ = the decomposed phase angle (Degree) of the radial force at harmonic *j* or frequency of 1/(j*T).
- T = the time taken for the tire to rotate one cycle at a specific speed.

Fx(i), Fy(i), MX(i), MZ(i) are all calculated in the same manner as Fz(i).

**5.1.1.3** The FFT is run on three (3) data sets:

- Composite data.
- Unbalance data.
- Assembly data (composite minus unbalance).

**5.1.1.4** Tire phase and magnitudes for the first 16 harmonics are calculated. Typically the first four (4) harmonics are of primary interest and are summarized in the report. Calculated harmonics should not exceed half the pulse count of the encoder. Also, reported harmonics should not exceed the capability of the machines in terms of machine natural frequency's influence on accuracy of the data.

**5.1.1.5** Phase angle is reported in degrees as a physical spot on the tire, measured CW from the valve stem of the assembly. The phase angle is always positive, so the $n^{th}$ harmonic phase angle can only be from 0/n through 360/n. Any phase angle adjustments due to mounting, are made after the FFT.

**5.1.2 Machine Contribution.**

**5.1.2.1** Machine contributions may be quantified periodically. There are two (2) primary uses for this information:

- As a check to quantify the machine effect on HSU data compared to historical levels, or
- To remove the machine effects from a specific data set such as a large sample of audit tires. In the last case, the machine contribution can be removed from both the composite and assembly data sets through vector subtraction.

**5.1.2.2** Machine contributions can be easily calculated provided the angle of rotations are all equal in magnitude, and that a complete set of orientations have been measured. The machine contribution is then the average of the vectors for a given parameter and harmonic.

**5.1.2.3** In general, machine contributions are expected to be relatively small with respect to the magnitudes of HSU being measured. If this is not true, then effort should be focused on reducing the magnitude of the machine contributions through root cause analysis of the HSU measurement system.

**5.1.2.4** Through historical monitoring of machine contributions, one can discern the acceptability of the current equipment state and potentially identify maintenance issues.

**5.2 Interpretation of Results**. The requester of the test will review the measured data, according to their specific needs.

**5.3 Test Documentation**. The data information to input on Sample Reports in Appendix B - Data Sheet B1 is GM Proprietary. The test results documentation should include:

- Test results report (generated by Global Tire and Wheel Test System (GTWTS) if submitting XML files).
- Test result data files (Extensible Markup Language (XML) format).
- .dat files.

The list of required test data parameters is given in Appendix A.-Table A1. A sample test system report is given in Appendix B - Data Sheet B1. In Appendix C -Data Sheet C1, you will find an example of the Excel Report that can be found in the attachments section of the test system. This Excel report form is the most convenient for copying data from the report.

**Note**: For data being loaded into the Global Tire and Wheel Test System (GTWTS), submit electronically the test results data files (XML format) and other supporting files listed. GMW16590 defines the electronic file details, (e.g., file types, file naming convention, and detailed file formats) for the GTWTS.



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