GM	WORLDWIDE ENGINEERING STANDARDS	Test Procedure	GMW15206

Tire Residual Aligning Torque

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 procedure provides a test method suitable for determining the steady-state, on-center tire properties commonly known as the residual force and Residual Aligning Torque (RAT) properties of a tire.

1.2 Applicability. This procedure is applicable to light vehicle tires, passenger car and light truck.

1.3 Remarks.

1.3.1 Tire RAT properties influence the on-center performance of vehicles and are most commonly used during the analysis of leads and pulls within the vehicle's steering system. Quantifying the tire RAT properties can facilitate the understanding and simulation of the vehicle steering system performance.

1.3.2 The quantification of tire RAT properties requires the measurement of relatively small forces and moments present as the tire operates near zero slip and camber angles. Since these forces and moments are small in magnitude, the measurement equipment, surface curvature, surfaces textures, and procedures must be in substantial agreement to demonstrate the correlation of the test results.

1.3.3 Tire RAT properties are functions of many physical characteristics within a tire, including the carcass design, tread design, and manufacturing processes. Throughout this procedure, but specifically in the analysis section, properties will be described with prefixes of con and ply. These terms are in reference to conicity and plysteer terminology, respectively. In general, properties associated with conicity are due to process variation within the build process of the tire and their magnitudes, likewise, variation within a given sample. Properties associated with plysteer are more due to tire design and are generally repeatable within a given sample of the same design.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

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2.3 Additional References.

- Adhesive – 3M Three-M-ite Fine 120 grit Aluminum Oxide
- European Tyre and Rim Technical Organisation (ETRTO) Yearbook
- Rubber Manufacturers Association Publications
- The Tire and Rim Association (T&RA) Yearbook

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3 Resources

3.1 Facilities. Not applicable.

3.2 Equipment.

3.2.1 The MTS Flat-Trac equipment uses a cantilevered spindle fixture upon which tire and wheel assemblies may be readily mounted. The equipment provides steady-state loading of the tire against a flat textured surface. The equipment provides a means for steering the tire a specified amount about the Z-axis (slip angle) and about the X-axis (camber angle). A series of load cells connect the spindle to the frame of the machine.

3.2.2 The MTS Flat-Trac I machine consists of four (4) main systems which all contribute to the tire measurement system:

- Mechanical inputs.
- Roadway surface.
- Transducer system.
- Data acquisition.

3.2.2.1 Mechanical inputs during the test include the slip angle, camber angle, and radial load which are controlled through a closed-loop feedback system. Slip and camber angles are measured using rotational transducers located at the top and to the side of the machine, respectively. The load is measured by the F_z transducer in the load cell assembly. Changes in the mechanical inputs are provided by a set of hydraulic actuators.

3.2.2.2 The roadway surface includes the mechanical devices which supports the tire during the measurement process and provides the interface through which the forces and moments are reacted.

3.2.2.2.1 The test surface consists of an abrasive material glued to a steel belt. This material is 120-grit 3M-ite. This product is used to simulate the texture of a typical road surface. In order to more closely represent the road surface, the surface macro texture is reduced through a stoning process and broken-in prior to the initial use. See GMW15204 for the details regarding surface preparation.

3.2.2.2.2 The test surface is applied to a steel belt which wraps around a pair of drums and slides over a hydrostatic water bearing located under the contact patch of the test tire. This bearing must evenly react to the vertical forces generated within the tire footprint. The bearing must be oriented parallel to the spin axis of the test spindle and perpendicular to the wheel plane.

3.2.2.2.3 The roadway control system must control the speed, direction, and tracking of the roadway. Accurate belt tracking is important to the RAT test results as this test involves small slip angle measurements. The resulting slip angle of the test tire is the sum of the steered slip angle and that due to the lateral displacement of the belt over a given distance.

3.2.2.3 The transducer system must measure the five (5) forces and moments generated by the tire as well as the slip and camber angles and the load radius.

3.2.2.4 The data acquisition system must acquire the output from the transducers, translating those outputs into digital values and then converting those digital values into scaled engineering units.

3.2.2.4.1 The data acquisition method utilized for this procedure is described as revolution averaged data acquisition. This method uses a spindle tire spindle encoder to clock the data acquisition at a minimum rate of 256 pulses per revolution. A minimum of one (1) full revolution of data is collected and averaged to obtain a single value for each channel.

3.3 Test Vehicle/Test Piece.

3.3.1 The test tire must be free of all tags, tape, stones, or any other foreign material in the tread area.

3.3.2 The wheel must be selected properly to obtain the correct test results. The following should be considered when selecting the proper test wheel.

3.3.2.1 The wheel width must match that requested on the tire test request.

3.3.2.2 The wheel must have the proper rim flange contour for the test tire as required by the T&RA or equivalent.

3.3.2.3 If the RAT properties of only the tire are to be measured, then the selected wheel must be sufficiently stiff to minimize the contribution of wheel RAT to the measurement. If it is the assembly RAT that is of interest, then the wheel used on the production vehicle should be used for the RAT test.

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3.3.2.4 A spindle adaptor must exist to interface with the wheel bolt circle and pilot area to facilitate the mounting of the wheel on the machine.

3.3.2.5 A spacer set must exist to make the wheel plane coincide with the center of the machine's coordinate system. This space set compensates for the offset of the wheel being used for the RAT test.

3.3.3 The roadway surface must be free of foreign material including, but not limited to, oils, rubber dust or other rubber deposits from previous tests.

3.4 Test Time.

Calendar time:	1 d
Test time:	1 h
Coordination time:	0.5 h

3.5 Test Required Information.

3.5.1 The following information regarding the tire must be provided in order to facilitate the test:

- Construction number.
- Tire size.
- Service description.
- Supplier (manufacturer).
- Load rating.

3.5.2 The following information related to the desired test conditions must also be specified:

- Rim width.
- Load.
- Inflation pressure.

3.5.3 Providing the following information can be useful in identifying the data, but is not required for facilitating the physical testing**.**

- Tire type code.
- Brand name (e.g., Eagle RS-A).
- Sidewall type (e.g., Raised White Letters).
- Program designation.

3.6 Personnel/Skills.

3.6.1 Test operators must be trained in the safe operation of the measurement equipment. The measurement equipment, by necessity, involves moving parts and loading mechanisms which must be understood and operated using proper safety precautions.

3.6.2 Operators must be trained in the selection of test components and fixtures to facilitate the proper testing of the tires.

3.6.3 Operators must be trained to observe, and correct when necessary, the condition of the test surface. The condition and level of contamination of the surface will have a direct impact on the quality of the RAT test results.

4 Procedure

4.1 Preparation.

4.1.1 Thermally stabilize the test tire by storing in an area with an ambient temperature within 5 °C of the test machine environment for at least 24 h prior to testing.

4.1.2 Mount the test tire on the test wheel.

4.1.2.1 Follow approved mounting procedures, such as those published by the Rubber Manufacturers Association, when mounting the test tire onto the test wheels.

4.1.2.2 Inspect the tire bead and the bead seat of the wheel to insure this interface is free of damage, defects, and foreign material. Clean or replace test pieces as necessary.

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4.1.2.3 Use only a thin film of an approved mounting lubricant to facilitate proper tire mounting and bead seating. Excessive mounting lubricant can cause slippage at the tire/rim interface during testing.

4.1.2.4 Inspect the bead area of the mounted tire and wheel assembly to ensure the tire bead is firmly seated on the wheel.

4.1.3 Inflate the tire and wheel assembly 30 kPa above the required test inflation pressure and allow the tire to stabilize at room temperature.

4.1.3.1 If this is the first mounting of the test tire within the previous 24 h, then allow the assembly to stabilize for at least 3 h.

4.1.3.2 If the tire was previously mounted and inflated within the last 24 h period and is now being remounted, then the assembly needs to stabilize only for a period of 5 minutes which is approximately the amount of time needed to mount onto the test machine.

4.2 Conditions.

4.2.1 Environmental Conditions. The ambient temperature in the room where the measurement equipment is operating shall be controlled to 21 °C ± 3 °C to minimize the thermal gradients within the test equipment and instrumentation.

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 If load and inflation pressure conditions are not specifically provided, use the Standard Test Conditions in Table 1.

4.2.2.2 The standard test speed is 3.6 km/h.

Table 1: Standard Test Conditions

Tire Type	Load Range	Test Load	Inflation Pressure
Passenger Car Note 1	All	70% of tire's maximum Load Capacity	250 kPa
Light Truck Note 2	All	70% of the 350 kPa Load Capacity	350 kPa

Note 1: Passenger Car tires primarily intended for use on passenger cars. These tires are commonly referred to as P-metric tires in T&RA guidelines. This category includes the P-metric equivalents in the European Tyre and Rim Technical Organisation (ETRTO) and other standardizing bodies.
Note 2: Light Truck tire primarily intended for load bearing vehicles. These tires are commonly referred to as LT-metric tires in T&RA guidelines and also known as commercial tires in ETRTO and other standardizing bodies.

4.3 Instructions.

4.3.1 Mount the tire and wheel assembly onto the test machine spindle using the proper adapter and spacers.

4.3.2 Set the tire and wheel assembly inflation pressure to the test inflation pressure.

4.3.3 Break-in. Perform a break-in procedure, unless the tire has been tested within the last 30 minutes.

4.3.3.1 The break-in procedure is intended to relax residual, transient stresses within the tire due to packaging, storage conditions, or other causes by exercising the structural elements of the tire.

4.3.3.2 Set the roadway speed to 7.2 km/h.

4.3.3.3 Break-in Loading. Set the load to 60% of the tire's maximum load capacity.

4.3.3.4 Sequence through each of the following eight (8) slip angles, dwelling at each for approximately 5 s: -0.4 degrees, -0.2 degrees, 0.0 degrees, 0.2 degrees, 0.4 degrees, 0.6 degrees, 0.8 degrees, and 1.0 degrees.

4.3.3.5 Set the slip angle to 0 degrees.

4.3.3.6 Repeat the sequences from 4.3.3.4, with the load set to 70% of the tire's maximum load capacity.

4.3.3.7 Remove the load from the test tire.

4.3.3.8 Stop the roadway if the inflation pressure is adjusted by the operator.

4.3.4 Check the tire and wheel assembly inflation pressure and reset to the test inflation pressure.

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4.3.5 Inspect the test surface on the machine and remove rubber dust and debris as necessary.

4.3.6. Set the roadway direction. The first roadway direction will be for a clockwise rotation of the test assembly.

4.3.7 Set test speed. Set the roadway speed to the test speed.

4.3.8 Apply a skim load of 500 N.

4.3.9 Set the slip angle. The first slip angle in the test sequence will be -0.4 degrees.

4.3.10 Set Load. Set the test load to the first, or lowest, test load.

4.3.11 Stabilize Conditions. Allow the machine control system to achieve the commanded set points and allow the tire and wheel assembly to stabilize for one (1) complete revolution.

4.3.12 Collect Data. Collect the force and moment data for at least one (1) complete revolution of the test assembly. Spindle clocked data acquisition is preferred with at least 256 equidistant sampling locations per revolution.

4.3.13 Repeat sequence 4.3.12 for all remaining load conditions.

4.3.14 Return to a skim load of 500 N.

4.3.15 Repeat sequence 4.3.9 through 4.3.14 for all of the remaining slip angles (i.e., -0.2 degrees, 0.0 degrees, 0.2 degrees, 0.4 degrees, 0.6 degrees, 0.8 degrees, 1.0 degrees), beginning with 4.3.9.

4.3.16 Collect data with the tire and wheel assembly rotating in the counterclockwise direction by repeating sequence 4.3.7 through 4.3.15.

4.3.16.1 The test must be completed on the tire with it rotating in both the clockwise and counterclockwise directions. There are two (2) acceptable methods of changing the direction of tire rotation.

4.3.16.2 The first method is to reverse the roadway direction. For this method, the tire coordinate axis system must be rotated 180 degrees about the Z-axis to maintain the proper coordinate axis systems for the data. This method is the standard GM procedure.

4.3.16.3 The second method is to remount the tire and wheel assembly on the machine such that it will rotate in the counterclockwise direction during the test.

4.3.17 Remove the tire and wheel assembly from the machine and dispose of test pieces per disposition instructions.

5 Data

5.1 Calculations.

5.1.1 The following data analysis assumes the data is either acquired or has been preprocessed such that the following statements are true.

5.1.1.1 Data is represented in SI units.

5.1.1.2 Data sign conventions are consistent with the SAE International (SAE) coordinate system.

5.1.1.3 The data was collected using the data acquisition method described in the instructions section and has been averaged using complete revolutions of the tire.

5.1.1.4 Data was collected while the input conditions to the tire were held constant such that the resulting data can be considered steady-state.

5.1.1.5 The control variables, other than slip angle and roadway direction, were all essentially constant. This is important because their variations are not comprehended in the following analysis.

5.1.2 For a standard test, only the data from the test load of 70% of the tire's maximum load capacity is used in the data analysis.

5.1.3 Within a single load case, there will be a set of data for each rotational direction, clockwise (CW) and counterclockwise (CCW), with three (3) variables in each set; slip angle (α), lateral force (F_Y), and the aligning moment (M_Z)

5.1.4 Perform four (4) separate regressions to determine the following functions using a cubic relationship with respect to slip angle:

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