SAE International™

SURFACE VEHICLE RECOMMENDED PRACTICE

SAE J2717

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Tests to Define Tire Size (Geometry), Mass, and Inertias

1. Scope

This SAE Recommended Practice describes a trio of test methods which determine basic tire size (geometry), mass, and moments of inertia. The methods apply to any tire so long as the equipment is properly scaled to conduct the measurements for the intended test tire. The data are suitable for determining parameters for road load models and for comparative evaluations of the measured properties in research and development.

NOTE—Herein, road load models are models for predicting forces applied to the vehicle spindles during operation over irregular surfaces paved or unpaved. Within the context of this Recommended Practice, forces applied to the surface on which the tire is operating are not considered.

1.1 Procedures

Three procedures are specified. The first procedure determines the tire's undeflected radius, section width, and section height. The second determines the mass of the tire and of the wheel on which the tire is mounted. The third procedure determines moments of inertia about the three cartesian axes defined in Recommended Practice J2710.

1.2 Test Machines

No specific purpose built test machines are required to use the procedures in this Recommended Practice although individual test laboratories may have specific purpose built test machines for making certain measurements, for example, inertias. Each procedure can be applied using an ensemble of jigs and tools specific to itself. Example tools and jigs adequate for each procedure are specified within the tools and jigs section of the description of each specific procedure.

1.3 Rationale

This Recommended Practice was developed as part of a set of Recommended Practices intended to allow modelers to determine the parameters required by any of the common tire models for calculating spindle loads given the road surface profile from a single set of experimental results, and thus, to eliminate duplicate testing.

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2. References

2.1 Applicable Publications

The following publications form part of the specification to the extent specified herein. Unless otherwise indicated the latest revisions of all publications shall apply.

2.1.1 SAE PUBLICATIONS

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2047—Tire Performance Technology
SAE J2429—Free-Rolling Cornering Test for Truck and Bus Tires
SAE J2710—Modal Testing of Tires and Identification of Lower Order Tire Frequencies

2.1.2 OSHA PUBLICATION

Available from Rubber Manufacturers Association, 1400 K Street, NW, Suite 900, Washington, DC 20005, Tel: 202-682-4800, www.rma.org.

OSHA Standard 1910.177—Servicing Multi-piece and Single Piece Rim Wheels—Available in wall chart form as #TTMP-7/95

2.1.3 ISO PUBLICATION

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO Standard 17025—General requirements for the competence of testing and calibration laboratories

2.1.4 ASTM PUBLICATION

Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM 1502—05e1 Standard Test Method for Static Measurements on Tires for Passenger Cars, Light Trucks, and Medium Duty Vehicles

2.1.5 FMVSS PUBLICATION

Available from U. S. Department of Transportation, National Highway Traffic Safety Administration, Office of Communications and Consumer Information (NPO-502), 400 Seventh St., SW, Washington, DC 20590.

FMVSS 139—New Pneumatic Radial Tires for Light Vehicles

3. Definitions

The definitions that follow are of special meaning in this Recommended Practice and are either not contained in other Recommended Practices or are worded somewhat differently in this practice.

3.1 Wheel

A wheel is a rim together with the disc or spider that allows attachment of a rim to the vehicle's hubs. A wheel cross-section schematic is shown in Figure 1.

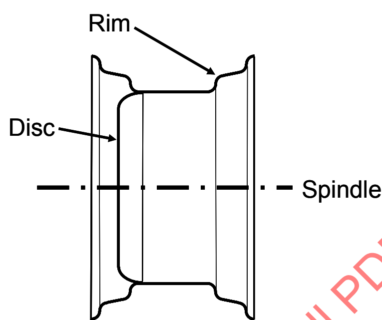

FIGURE 1—WHEEL CROSS-SECTION

3.2 Moments of Inertia

The moments of inertia are defined in the double primed axis system introduced in J2710. Figure 2 shows the J2710 axis system for the special case of no camber or inclination. That case applies in this Recommended Practice. The wheel is sketched in rear elevation. The view is forward along the X"—axis looking at the Y"—Z" plane. The system's origin is at the point that the spin axis intersects the wheel plane, which is the plane halfway between the rim flanges (J2047). The system is a right-handed, orthogonal, Cartesian system. The X" and Z" axes lie in the wheel plane. The Y"—axis is to the right. If the tire is mounted with the tire face to the right, as if it were on the right side of a vehicle, Y" is outward.

3.2.1 WHEEL MOMENTS OF INERTIA

3.2.1.1 Wheel Moment of Inertia about the Y"—Axis

This is the moment of inertia of the wheel alone about the Y"—Axis.

3.2.1.2 Wheel Moment of Inertia about the Z"—Axis

This is the moment of inertia of the wheel alone about the Z"—Axis. The moment of inertia of the wheel about the X"—Axis is the same due to wheel symmetry.

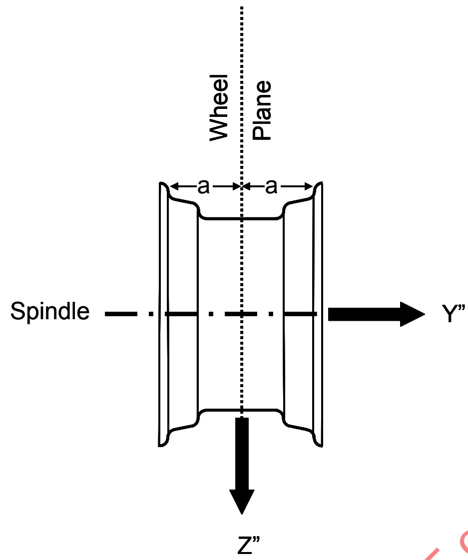

FIGURE 2—REAR ELEVATION VIEW OF THE DOUBLE PRIMED AXIS SYSTEM

3.2.2 TIRE MOMENTS OF INERTIA

3.2.2.1 Tire Moment of Inertia about the Y"—Axis

This is the moment of inertia of the tire alone about the Y"—Axis.

3.2.2.2 Tire Moment of Inertia about the Z"—Axis

This is the moment of inertia of the tire alone about the Z"—Axis. The moment of inertia of the tire about the X"—Axis is the same due to tyre symmetry.

NOTE—The moments of inertia about the X" and Z" axes are not necessarily identical to those about axes through the center of gravity of the tire-wheel assembly. This is due to a possible offset of the c.g. from the origin of the X", Y", Z" Axes System along the Y"—Axis. This offset, when present, arises from an offset wheel disc and tire asymmetries and requires application of the parallel-axis theorem, which is applied in 13.5, and is discussed in all engineering dynamics books, as noted in footnote 6.

3.2.3 MASSES

3.2.3.1 Wheel Mass

This is the mass of the wheel alone in the absence of a tire.

3.2.3.2 Tire Mass

This is the mass of the tire alone in the absence of a wheel.

3.3 Tire Un-deflected Radius

This is one-half of the Tire Overall Diameter as defined in J2047.

3.4 Test

A test is execution of the procedures described in this Recommended Practice one time on one tire at a single set of test conditions.

3.5 Test Program

A test program is a designed experiment involving a set of the tests described in this practice.[1]

4. Nomenclature

Table 1 lists the symbols used in this document. For further information on items not in Section 4 of this practice please see SAE J2047.

TABLE 1—SYMBOLS DEFINED

Symbol	Defined Term
d_T	Y" offset of the tire c.g. from the X"/Z"— plane
d_W	Y" offset of the wheel c.g. from the X"/Z"— plane
k	Stiffness of Torsional Pendulum
I_C	A Calibration Inertia for the Torsional Pendulum
I_0	Residual Inertia of Torsional Pendulum
I_{YYT}	Tire Inertia about the Y"—Axis
I_{ZZT}	Tire Inertia about the Z"—Axis
I_{YYW}	Wheel Inertia about the Y"—Axis
I_{ZZW}	Wheel Inertia about the Z"—Axis
M_T	Tire Mass
M_W	Wheel Mass
M_{IT}	Inner Tube Mass
p	Inflation Pressure
R_0	Tire Undeflected Radius
σ	Standard Deviation (Note Subscripts)
SH	Section Height
SW	Section Width
T	Period of Oscillation

NOTE 1—If mass, Y" offset of the c.g., or inertia appears with the subscript, WT; this signifies that the entire tire/wheel assembly is being considered.

NOTE 2—The period of oscillation may appear with a subscript indicating the state of the torsional pendulum when the data are taken. For example, T_0 would be the period if the only inertia present were the residual inertia.

[1] There are many experimental possibilities: repeated tests of the same tire, tests of the same tire under multiple test conditions, tests of tires with different specifications (design details), application of this test as part of a series of different tests, etc.

5. Laboratory Quality System Requirement

The laboratory performing the procedures specified in this Recommended Practice shall have a quality system either conforming to ISO 17025 or which can be shown to be functionally equivalent to ISO 17025. The elements of such a system are assumed below and are not, therefore, specifically called out within this practice.

6. Calibration

Calibrate all measuring tools in accordance with the mandates of the written plan required by the laboratory quality system referenced in Section 5. Calibration must exercise all measuring tools over substantially their full range of application and must be performed not less than once each year. The reference standards and instruments used in measuring tool calibration shall be traceable to the National Institute of Standards and Technology or other appropriate national standards organization with jurisdiction at the laboratory's location. Currently valid calibration certificates for reference standards and instruments shall be on file at the testing laboratory when the tools used in accordance with this Recommended Practice are calibrated. Gains, offsets, and other pertinent performance measures and comments on the behavior of measuring tools arising from calibrations shall be kept permanently on file within the testing laboratory's archives and be available to customers on request.

7. Preparation of Apparatus

Preparation of the tools and jigs forming the apparatus used in each procedure shall ensure that the test setup meets calibration at the outset of each test program. The precise process control method used to verify readiness of the apparatus is likely to be unique to an individual test site, but must be specified in writing within the quality system of the laboratory. The results of process control experiments shall be available to customers on request.

8. Test Wheels

Test wheels should ideally be those specified by the test requester or supplied by the test requester due to the intent of this Recommended Practice to provide mass and moment of inertia properties of the wheels as well as of the tires. Should the precise wheels be unavailable a rational alternative choice should be made with the concurrence of the test requester. In any case, test wheels shall meet the dimensional tolerances of original equipment wheels supplied on new vehicles and match the rim profile for the applicable tire as specified by the appropriate tire and rim standards association, for example, the Tire and Rim Association, Inc.

9. Selection and Preparation of Test Tires

9.1 Selecting the Tires for Good Comparability

The purpose of the test must be carefully borne in mind when selecting test tires since tire properties depend on numerous factors besides the tire design and materials. It is especially important to properly account for storage history (SAE 810066) and previous work history (SAE 770870). Due to the many questions that the test defined in this document may be used to address, specific tire selection recommendations can only be made for the case in which different tires are to be compared for pure design effects. In that case, all test tires should be of approximately the same age, have been stored under essentially identical conditions, have experienced approximately the same exercise history, and have been sampled from production lots with similar statistical characteristics.

9.2 Inflation Pressure

The inflation pressure will significantly affect tire inflated geometry. Therefore, the appropriate test inflation pressure must be specified by the requester. Because tires typically operate at a temperature higher than that of the ambient air, operating inflation pressure is usually higher than cold inflation pressure. If the purpose of testing is to simulate the running state, then the inflation pressure used in the test must be equivalent to the on-road operating inflation pressure. The laboratory is assumed to be capable of setting cold tire inflation pressure to within ±1.7 kPa.[2]

9.3 Tire Preparation

Clean the tire surface of dirt, loose material, or other contaminants. Mount the test tire on the test requester specified test wheel. For rim wheels[3] used on large vehicles such as trucks, tractors, buses, and off-road machines, mounting and demounting shall be done in accordance with the practices specified in (OSHA 1910.177). (OSHA 1910.177) does not apply to the servicing of rim wheels used on automobiles or on pickup trucks and vans utilizing automobile tires or truck tires designated “LT”. The wheel used shall meet the specifications noted in Section 8. After mounting, the tire shall be marked with three sets of radial lines from bead-to-bead. These lines shall be spaced every 120° degrees circumferentially around the spin or Y”—Axis with the 0° line located at the DOT serial number on tires with a DOT serial number. In the case of tires without a DOT serial number a 0° location agreeable to the test requester shall be chosen.

9.4 Sample Size

Typically, a single tire selected at random from among the group of tires in each specification is an adequate sample if the goal is parametric data for producing a tire model. However, should the desire be to determine differences between tire specifications at a stated level of accuracy it will be necessary to use statistically valid sample sizes and to employ appropriate statistical analyses of the results to define the differences among specifications.

10. Experimental Environment

All procedures shall be carried out in a laboratory space maintained at normal office humidity and a temperature of 22 °C ± 2 °C.

11. Tire Size Procedure

This procedure determines Tire Undeflected Radius, Section Width and Section Height. These are reported as three numbers reported in millimeters. The procedure is related to the procedure explained in ASTM F1502-94, but is simpler and less complete.

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2 If the laboratory is incapable of setting tire inflation pressure to the assumed accuracy, the test requester shall be informed before testing commences.

3 Rim wheel is a non-standard phrase used in OSHA 1910.177. It is used here for consistency with the OSHA document.

11.1 Required Measurement Tools

11.1.1 Steel tape with a ±0.5 mm or better accuracy.

11.1.2 Calipers with a ±0.5 mm or better accuracy.

11.1.3 Depth gauge with a ±0.1 mm or better accuracy.

11.2 Prior to Performing the Procedure

The test tire and wheel shall be in the test space for 24 hours or more prior to execution of the Tire Size Procedure.[4] At the beginning of the 24 hour period the tire shall be mounted on the test wheel and inflated to the test inflation pressure. Immediately prior to performing the measurements described in 11.3, 11.4, and 11.5 check and adjust the test inflation pressure if necessary.

11.3 Determination of Undeflected Radius

The end of the tape is anchored at the crown of the mounted and inflated tire or at a nearby maximum radius location and carefully stretched circumferentially around the tire parallel to the tire-wheel plane. The circumference is recorded and then divided by 2π to yield the undeflected radius. If a pi—tape is used, the diameter is read directly.

11.4 Determination of Section Height

One-half of the wheel's nominal diameter is subtracted from the tire's undeflected radius to determine Section Height.

NOTE—As noted in J2047, the nominal rim diameter is the figure in the rim specification which designates or approximates the rim diameter. For example, in the case of an 18 X 10J—ISO wheel, 18 is the nominal diameter expressed in inches.

11.5 Determination of Section Width

The overall width of the tire is measured at each of the three marked locations determined by the tester or specified by the test requester[5] using the calipers and the results recorded. Overall width includes protective ribs, bars, and decorations which are common on tire sidewalls. The height of the protective ribs, bars, and decorations included in the overall width measurement at a marked location is determined using the depth gage. The results are recorded for use in Section Width calculation.

The Section Width, which does not include protective ribs, bars, and decorations, is determined by subtractiing the height of the bars, etc. from the overall width at each of the three marked locations. The reported value of Section Width is the average of the results for each of the three individual marked locations.

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[4] The 24 hour period was chosen for consistency with T&RA practice and the inflation time before dimensional measurements specified in FMVSS 139, the replacement for FMVSS 109. This Recommended Practice deviates from FMVSS 139 dimensional practice in that the temperature during the pre-measurement period in this practice is 22 °C ± 2 °C laboratory temperature not 38 °C as required in the Federal Motor Vehicle Safety Standard.

[5] If the test requester makes no location specifications, the locations are specified by the tester.

12. Mass Procedure

This procedure determines the Tire Mass and the Wheel Mass. These are reported as two numbers expressed in kg.

Should an Inner Tube be used its mass will be reported as a separate number expressed in kg.

12.1 Required Measurement Tools

A scale capable of weighing the tire or wheel to an accuracy of ± 0.1% of the scale's range or better is required.

NOTE—To obtain measurements with good accuracy and resolution, measurement of the lighter of the tire or wheel should use at least 10 percent of the scale's range.

12.2 Determination of Mass

The scale is zeroed or a tare reading is taken. Then the unmounted tire is weighed. The resulting weight[6] corrected for scale tare is divided by the acceleration of gravity and the result reported in kilo-grams.

The scale is zeroed or a tare reading is taken. Then the wheel alone is weighed. The resulting weight corrected for scale tare is divided by the acceleration of gravity and the result reported in kilograms.

Should an inner tube be used the scale is again zeroed or a tare reading is taken. Then the inner tube alone is weighed. The resulting weight corrected for scale tare is divided by the acceleration of gravity and the result reported in kilograms.

13. Moment of Inertia Procedure

This procedure determines Wheel Moment of Inertia about the Y"—Axis, Wheel Moment of Inertia about the Z"—Axis, Tire Moment of Inertia about the Y"—Axis, and Tire Moment of Inertia about the Z"—Axis. These are reported as a series of four numbers with units of kg—m^2. Should an inner tube be used, it is mounted normally in the tire, and its inertia is considered as part of the tire inertia. To avoid confusion, the test report will note that the results reported for the tire are actually for a tire/inner tube combination. It is understood that the term tire in the inertia discussion refers to either a tire or a tire/inner tube combination which ever is relevant in the particular test.

The procedure employs a torsional pendulum, which in concept is an inertia mounted on a torsional spring. A single degree of freedom, second order, differential equation describing undamped free oscillation can be taken to describe the behavior of the torsional pendulum. Frequency solution of this equation and a bit of substitution leads to Equation 1, which shows that the inertia in the system is a linear function of the square of the pendulum's period of oscillation. A torsional pendulum is described in greater mechanical detail in the remainder of this section.

$$I = k\,[(T^2)/(2\pi)^2] \qquad \text{(Eq. 1)}$$

[6] It is assumed that the weight is provided in force units.

The pendulum may be either a commercially constructed torsional pendulum built for the specific purpose of obtaining the data discussed in this Recommended Practice or a laboratory prepared torsional pendulum assembled from basic components. Many torsional pendulums including most commercially constructed torsional pendulums along with associated mounting chucks have appreciable inherent inertia that must be accounted for by a method analogous to that discussed in 13.2.1.

An example low inherent inertia laboratory prepared pendulum design is discussed in detail to provide clarity and to illustrate a way to conduct this measurement without much investment. The example design is calibrated as discussed in 13.2.2. Obviously, other laboratory developed designs are possible.

There is no requirement that any particular design be used. Any functionally equivalent procedure using other torsional pendulum equipment, which supports the test sample, allows the sample to oscillate, and determines the period of oscillation, to provide equivalent data is satisfactory.

13.1 Required Measurement Tools

A torsional pendulum contains elements, which achieve all the functions noted below. Unless otherwise noted the specific elements discussed apply to the example design when it is used on passenger car tires and wheels. Appropriate resizing of the example design would be required to test tires other than passenger tires and smaller light truck tires.

13.1.1 TIMER

This determines the period of the torsional oscillations for the pendulum with a test tire, wheel, or tire/wheel assembly mounted. In the example approach a stopwatch is an adequate timer.

13.1.2 POSITION INDICATOR

This is an angular motion reference for the oscillating sample that allows detection of complete oscillation cycles. In the example approach a stand with a pointer is adequate.

13.1.3 TORSIONAL PENDULUM

The torsional pendulum constrains the test piece to oscillate torsionally around a defined axis. This motion can be achieved by using a table or chuck with support bearings or flexures. In the case of a pendulum with a table and a chuck there is typically an appreciable potentially unknown moment of inertia that affects the results. Dealing with this unknown moment of inertia is discussed in 13.2.1.

The example (low inertia) pendulum design implements the special case in which the axis of the pendulum passes through the center of gravity of the test sample. Bearings and flexures are not required in this case. In the example design the tire, wheel, or tire/wheel assembly is deliberately positioned such that its center of gravity lies on the axis of the torsional pendulum. If the tire/wheel brackets used in this case are designed to have inertias of only a few hundreths of a kg-m^2, the calibration procedure is simplified as noted in 13.2.2.

Sections 13.1.3.1 – 13.1.3.4 discuss the parts from which the example, low inertia, torsional pendulum can be assembled. The example is a vertical torsion bar secured to an overhead beam with the tire, tire/wheel assembly, or the wheel secured to the lower end of the torsion bar. The center of gravity of the test sample is coincident with the vertical axis of the torsion bar. The required parts for the example pendulum sized for passenger or small light truck tires are: a beam bracket, a torsion bar, a tire/wheel/bracket, and several locknuts.

13.1.3.1 Beam Bracket

This is a bracket for securing the torsion bar to an overhead beam. The attachment between the bracket and the bar is designed to prevent relative motion between the two pieces. One way to limit relative motion is to secure the torsion bar to the beam bracket by screwing the bar into a threaded hole in the bracket and locking it in place using a locknut, see 13.1.3.4.

13.1.3.2 Torsion Bar

This thin bar is a long rod adapted to mount to the beam bracket at one end and the tire/wheel bracket at the other. The bar is sized to produce slow oscillations for the expected inertias of the test pieces. It attaches to the beam bracket at the top and the tire/wheel bracket at the bottom. For passenger car tires and wheels, a 6.35 mm (1/4th in) diameter steel rod about 3.0 m long threaded on both ends is satisfactory. It's stiffness in N-m/rad is easily calculated, but need not be known as is explained in 13.2.2.

13.1.3.3 Tire/Wheel Brackets

These brackets are for securing the test tire, tire/wheel assembly or the wheel to the torsion bar. The attachment between the brackets and the bar is designed to prevent relative motion between the two pieces. One way to limit relative motion is by screwing the bar into a threaded hole in the tire/wheel bracket and locking it in place using a locknut, see 13.1.3.4. A small ensemble of these brackets is actually required as the same one is not suitable for all uses as is apparent from the following discussion.

The center of gravity of the wheel or tire/wheel assembly lies on the Y"—Axis so a very simple two piece bracket is adequate for testing to determine the moment of inertia about Y". The two pieces can be machined to clamp into the wheel's center (pilot) hole such that the test piece cannot move relative to the bracket.

For testing about the Z"—Axis, which is halfway between the rim flanges along the Y"—Axis, the bracket used with the example design can come in two basic forms. It depends on how the test engineer decides to work to assure that the test piece center of gravity lies on the torsional axis of the pendulum. In ether case the determination of the moment of inertia about the Z"—Axis depends on application of the parallel-axis theorem.[7]

If the pendulum has bearings or flexures that force rotation about the torsional axis of the pendulum, as in the case of a commercially produced torsional pendulum, a practical bracket for testing about the Z"—Axis is a chuck or an ensemble of bolts and clamps which rigidly affixes the test piece to the torsional spring.

[7] The parallel-axis theorem is discussed in all engineering dynamics books. Thus, the engineer is referred to the book with which he or she is most familiar.

In case of the example approach, a pendulum without bearings or flexures, either the tire/wheel bracket must be mounted off-center with respect to the X"/Z"—plane at the Y" location of the center of gravity or the bracket must allow movement of the center of gravity so it will coincide with the axis of the torsion bar after the bracket is mounted at Y" = 0.

In the case of off-center tire/wheel bracket mounting, the Y" location of the center of gravity must be determined prior to mounting. This can be done by any method described in an enginering statics or dynamics book and is not discussed in this Recommended Practice though the result is assumed.

Given the Y" location of the center of gravity the tire/wheel bracket attachment process is unique in two ways. First, the attachment to the tire or tire/wheel assembly is at the Y" location of the center of gravity, not at Y" = 0. Second, the tire/wheel bracket must have upper and lower sections pinned together so as to allow for the slope of the tire surface in the Y"/Z" plane at the center of gravity location. A concept for such a bracket as a clevis is sketched in Figure 3.

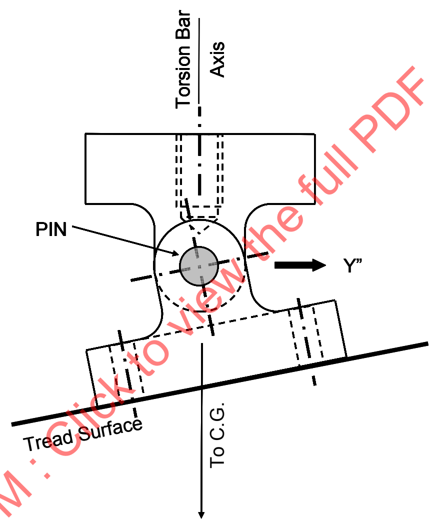

FIGURE 3—SIDE VIEW OF CONCEPTUAL TIRE/WHEEL BRACKET FOR USE IN MOUNTING AT THE Y" POSITION OF THE CENTER OF GRAVITY

In the example design, if the Y" location of the center of gravity is not premeasured, the tire/wheel bracket must allow the test piece center of gravity to be moved horizontally after attachment of the bracket at Y" = 0. This permits the test specimen center of gravity to line up with the axis of the torsion bar. This can be accomplished by introducing a mounting slide between the tire/wheel bracket and the test piece. The slide allows the tire or tire/wheel assembly to be moved left to right relative to the axis of the tire/wheel bracket until the Y"-Axis of the test piece is horizontal. Inclusion of a level bubble as part of the lower half of the bracket or of the slide as shown in Figure 4 and use of the additional tire mounting member allows the test engineer to attach the tire to the bracket, slide the tire until the Y"—Axis is level, lock the slide laterally, measure the Y" component of the center of gravity offset from the wheel plane (d), and conduct the moment of inertia measurement about the center of gravity.

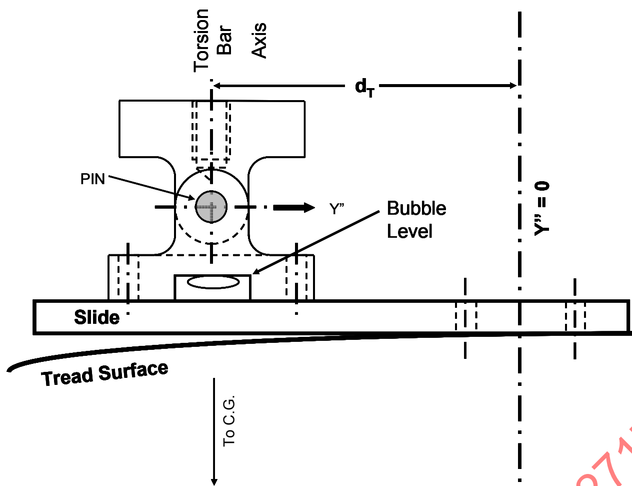

FIGURE 4—SIDE VIEW OF CONCEPTUAL TIRE/WHEEL BRACKET FOR USE IN MOUNTING AT THE Y" = 0 POSITION AND THEN ADJUSTING UNTIL THE C.G. IS IN LINE WITH THE TORSION BAR AXIS

13.1.3.4 Lock Nuts

In the example design these nuts lock the torsion bar to the brackets preventing relative angular motion between the bar and the brackets, as noted in 13.1.3.2.

13.1.4 INERTIA REFERENCES

These are objects with calcuable/known moments of inertia. They are designed to be installed with their center of gravity coincident with the pendulum's axis of rotation and are used to calibrate the pendulum just as standard weights are used to calibrate scales. One inertia reference can be sufficient, but several may be required dependent on the calibration approach chosen.

In the example design where the tooling has an effective inertia of only a few hundreths of kg-m^2, which can be effectively neglected, a single round steel bar about 75cm long with a diameter in the range of 3.8 to 4.5cm is an effective reference when testing passenger tires. It can be threaded at its c.g. to bolt to the bottom of the torsion bar in place of the tire/wheel bracket.

13.2 Setup and Calibrate the Pendulum

Section 13.2.1 is an example of how a pendulum with appreciable inherent inertia might be calibrated. It is assumed that such a pendulum is setup and ready for use. There is no requirement to use the method outlined in 13.2.1 in calibration. If the pendulum is a commercial device, it should be setup and calibrated according to the instructions provided by its manufacturer.

If the example design is followed, the pendulum should be prepared for use as described in 13.2.2 or by an equivalent method devised by the test laboratory and agreeable to the test requester. Since this is not usually a pre-placed piece of apparatus, setup is also considered.

13.2.1 CALIBRATING A TORSIONAL PENDULUM WITH AN APPRECIABLE INHERENT INERTIA

13.2.1.1 Test with Only Inherent Inertia Considered

With only the chuck/bolts/brackets and so forth to be used in the actual tire/wheel test in place determine the period of oscillation, T_0. This will produce Equation 2.

$$I_0 = k\,[(T_0^2)/(2\pi)^2] \quad \text{(Eq. 2)}$$

13.2.1.2 Test with the Inertia Reference Mounted

With the chuck/bolts/brackets and so forth to be used in the actual tire/wheel test in place attach the inertia reference and determine the period of oscillation, T_C. This will produce Equation 3.

$$I_0 + I_C = k\,[(T_c^2)/(2\pi)^2] \quad \text{(Eq. 3)}$$

13.2.1.3 Solve Equations 2 and 3 Simultaneously

The result will be values for k and I_0 as given in Equations 4 and 5. With these in hand it is possible to test for the inertias of the test pieces.

$$k = I_C\,[(2\pi)^2/(T_C^2 - T_0^2)] \quad \text{(Eq. 4)}$$

$$I_0 = I_C\,[(T_C^2)/(T_C^2 - T_0^2)] \quad \text{(Eq. 5)}$$

NOTE—It is possible to use several inertia references and produce a linear fit of inertia versus the square of the period without ever determining either k or I_0. This relationship then allows determination of test piece inertia from the pendulum period.

13.2.2 CALIBRATING A TORSIONAL PENDULUM WITH NEGLIGIBLE INERTIA

The specific case is that of the example design, but a skilled engineer can readily proceed in a required analogous fashion.

13.2.2.1 Attach Torsion Bar to Beam Bracket

Attach the torsion bar securely to the beam bracket so that relative motion cannot occur.

13.2.2.2 Attach Inertia Reference

Attach the inertia reference securely to the torsion bar so that relative motion cannot occur.

13.2.2.3 Scribe a Reference Mark

Place a mark or marker on the inertia reference that will allow its angular position in the horizontal plane to be easily determined with respect to the pointer. For the example inertia reference in 13.1.4 scribe a vertical diametral line across the end of the reference bar.

13.2.2.4 Setup Pointer

Set the stand and pointer in position so that the pointer is directed at the reference mark with the pendulum not oscillating.

13.2.2.5 Determine the Period of the Pendulum with the Inertia Reference in Place

13.2.2.5.1 Rotate the inertia reference through a modest angle in the horizontal plane.

13.2.2.5.2 Release the inertia reference.

13.2.2.5.3 Determine the oscillation period by using the stopwatch to measure 8 to 10 oscillations of the pendulum. Record the time required and the number of oscillations.

13.2.2.5.4 Repeat 13.2.2.5.1 through 13.2.2.5.3 five times then add the total number of oscillations timed and the time required for the timed oscillations. Then, applying Equation 6 determine the period of oscillation during inertia calibration. This value shall be recorded as T_c for use in Equation 7.

$$T = (\text{Required Time}) / (\text{Number of Oscillations}) \qquad \text{(Eq. 6)}$$

13.2.2.5.5 Remove the inertia reference and set it aside.

13.3 Determine the Moments of Inertia about the Y"—Axis

The discussion of this section assumes the use of a torsional pendulum similar to the example design. Use of other equivalent devices should be intuitively obvious based on the discussion that follows.

NOTE—The specific order of operation that follows is just one that is convenient when using the example pendulum design. Any order of operation that results in production of the required data is acceptable.

13.3.1 MEASURE THE WHEEL OSCILLATION PERIOD

This value shall be recorded as T_{YYW} for use in Equation 7. This is done in a manner analogous to the measurement of T_c discussed in 13.2.

13.3.2 MEASURE THE TIRE/WHEEL ASSEMBLY OSCILLATION PERIOD

This value shall be recorded as T_{YYWT} for use in Equation 8. This is done in a manner analogous to the measurement of T_c discussed in 13.2.

13.3.3 COMPUTE THE MOMENTS OF INERTIA ABOUT Y”

13.3.3.1 Y” Moment of Inertia of the Wheel

Using Equation 7 and the values of T_C and T_{YYW} compute I_{YYW}.

$$I_{YYW} = I_C\,[(T_{YYW})^2/(T_C)^2] \qquad \text{(Eq. 7)}$$

Record and retain the value of I_{YYW} , which shall be reported.

13.3.3.2 Y” Moment of Inertia of the Wheel/Tire Assembly

Using Equation 8 and the values of T_C and T_{YYWT} compute I_{YYWT}.

$$I_{YYWT} = I_C\,[(T_{YYWT})^2/(T_C)^2] \qquad \text{(Eq. 8)}$$

Record and retain the value of I_{YYWT}.

13.3.3.3 Y” Moment of Inertia of the Tire

Using Equation 9 compute I_{YYT}.

$$I_{YYT} = I_{YYWT} - I_{YYW} \qquad \text{(Eq. 9)}$$

Record and retain the value of I_{YYT}, which shall be reported.

NOTE—If a system with appreciable inherent inertia had been used to determine the test piece oscillation periods, the information determined using the methods described in 13.2.1 would have been applied to define IYYW, IYYT, and IYYWT in conjunction with an equation like Equation 10.

$$I_{test} = \{[k(T_{test})^2/(2\pi)^2] - I_C\} \qquad \text{(Eq. 10)}$$

13.4 Determine the Moments of Inertia about the Z”—Axis for a Pendulum with a Mechanically Defined Axis of Rotation

This is in practice an assumption of a pendulum with appreciable inherent inertia or a enhanced version of the example design. In the case of the pendulum with an appreciable inertia and a defined axis of rotation, the test tire, wheel, or tire and wheel are mounted such that the Z”— Axis is coincident with the torsional axis of the pendulum and the experiment proceeds according to the philosophy in the note under 13.3.3.3.

In the case of an enhanced version of the the example design involving bearings around the test specimen mounting end of the torsion bar things would be done as follows.