SAE International	SURFACE VEHICLE RECOMMENDED PRACTICE	J2730	ISSUED AUG2006
		Issued 2006-08	

Dynamic Cleat Test with Perpendicular and Inclined Cleats

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. These documents provide the necessary data from a single set of experimental results, thus, eliminating duplicate testing.

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1. SCOPE

This SAE Recommended Practice describes a test method for measuring the forces and moments generated at a high frequency response spindle when a rolling tire impacts a cleat. The cleat is configured either with its crest perpendicular, 90°, to the path of the tire or optionally with its crest inclined at an angle to the path of the tire. The carriage to which the spindle is attached is rigidly constrained in position during each test condition so as to provide a good approximation to fixed loaded radius operation. The method discussed in this document provides impact force and moment time histories essentially free from variations due to tire non-uniformities. The method applies to any size tire so long as the equipment is properly scaled to conduct the measurements for the intended test tire. The data are suitable for use in 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 otherwise. Within the context of this document, forces applied to the road or terrain surface are not considered.

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 and Identification of Lower Order Tire Natural Frequencies of Radial Tires

SAE J2717 Tests to Define Tire Size (Geometry), Mass and Inertias

SAE 2001-01-0790 Dynamic Force Measurement System (DFMS) for Tires, G. R. Potts and E. F. Knuth, 2001

SAE 770870 The Effect of Tire Break-in on Force and Moment Properties, K. D. Marshall, R. L. Phelps, M. G. Pottinger, and W. Pelz, 1977

SAE 810066 The Effect of Aging on Force and Moment Properties of Radial Tires, M. G. Pottinger and K. D. Marshall

2.1.2 Rubber Manufacturers Association 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 ANSI, 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

3. DEFINITIONS

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

3.1 The Parallel Axis Tire Coordinate System

This system is the one defined in SAE J2710 extended to allow tire rotation.

The loaded tire for the purpose of this document is defined as a tire/wheel assembly attached to the spindle. The spindle is considered to be substantially rigidly supported in the longitudinal, lateral, and vertical directions[1]. The tire is free to rotate about the spindle. The tire is loaded in contact with the reaction (test machine) surface so as to produce a tire footprint. The principal directions are defined in terms of a right-handed Cartesian coordinate system with its origin at the intersection of the spindle and the wheel plane. The three axes are defined as follows and illustrated in Figure 1.

[1] The vertical direction is sometimes referred to as the normal or radial direction dependent on the context.

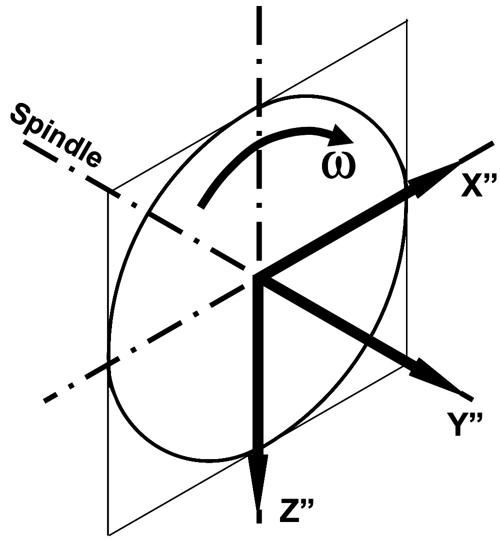

FIGURE 1 - THE SAE PARALLEL AXIS SYSTEM

3.1.1 Parallel System Longitudinal Axis, X”

The parallel system longitudinal axis is parallel to the SAE X’—Axis as defined in SAE J2047. It is positive in the direction of rolling as indicated in Figure 1.

3.1.2 Parallel System Lateral Axis, Y”

The parallel system lateral axis is parallel to the SAE Y’—Axis as defined in SAE J2047. Its positive sense is to the right as viewed from behind the Y”—Z” Plane.

NOTE: In the case of a tire without inclination, as assumed in this document, Y” lies along the spindle center line with a positive sense to the right.

3.1.3 Parallel System Vertical Axis, Z”

The parallel system vertical axis is perpendicular to the road plane with a positive sense into the road surface. It is parallel to the SAE Z’—Axis as defined in SAE J2047, but the origin of the vertical axis is at the center of the tire not at the road surface.

NOTE: The tire is assumed to have no inclination in this document in which case Z” lies in the wheel plane.

3.1.4 Spin Velocity, ω

The tire spin velocity is about the spindle, which is coincident with the Y”—Axis in the case considered in this document.

3.2 The Tire Forces and Moments

In this document, the forces and moments originate at the origin of the double primed axis system. They are shown in Figure 2 and are defined below. They are considered as being forces and moments applied to the spindle by the vibrating tire/wheel assembly. After this section and use in Table 1, these forces and moments are simply referred to as tire forces and moments. This is done for reasons of simplicity. In the definitions, these forces and moments are named to clearly associate them with the parallel axis system. These are the only forces and moments under discussion in this document.

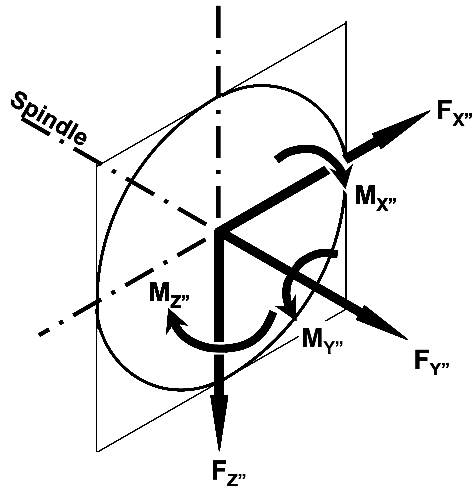

FIGURE 2 - SAE PARALLEL AXIS SYSTEM FORCES AND MOMENTS

3.2.1 Parallel Axis Longitudinal Force, $F_{x''}$

The parallel axis longitudinal force is along the X"—Axis. It is positive in the direction of the positive X"—Axis. The force acts from the tire onto the spindle.

3.2.2 Parallel Axis Lateral Force, $F_{y''}$

The parallel axis lateral force is along the Y"—Axis. It is positive in the direction of the positive Y"—Axis. The force acts from the tire onto the spindle.

3.2.3 Parallel Axis Normal Force, $F_{z''}$

The parallel axis normal force is along the Z"—Axis. It is positive in the direction of the positive Z"—Axis. The force acts from the tire onto the spindle.

3.2.4 Parallel Axis Overturning Moment, $M_{x''}$

The parallel axis overturning moment is about the X"—Axis. It is positive clockwise about the positive branch of the X"—Axis. The moment acts from the tire onto the spindle.

3.2.5 Parallel Axis Rolling Resistance Moment, $M_{y''}$

The parallel axis rolling resistance moment is about the Y"—Axis. It is positive clockwise about the positive branch of the Y"—Axis. The moment acts from the tire onto the spindle.[2]

3.2.6 Parallel Axis Aligning Moment, $M_{Z''}$

The parallel axis aligning moment is about the Z"—Axis. It is positive clockwise about the positive branch of the Z"—Axis. The moment acts from the tire onto the spindle.

2 The rolling resistance moment is included for completeness, but is neither measured nor utilized in this document.

3.3 Travel Distances

3.3.1 Angular Displacement of the Tire, Φ

The angular displacement about the spindle defined to be zero at the instant the data acquisition trigger occurs.

3.4 Test

A Test is execution of the procedure described in this document one time on one tire at a single set of conditions.

3.5 Test Program

A Test Program is a designed experiment involving a set of the tests described in this practice.[3]

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
$F_{X''}$	Parallel System Longitudinal Force
$F_{Y''}$	Parallel System Lateral Force
$F_{Z''}$	Parallel System Normal Force
Φ	Tire Angular Displacement
$M_{X''}$	Parallel System Overturning Moment
$M_{Y''}$	Parallel System Rolling Resistance Moment
$M_{Z''}$	Parallel System Aligning Moment
p	Inflation Pressure
R_l	Tire Loaded Radius
t	Time
V	Test Velocity
ω	Tire Spin Velocity
Ω	Test Roadway Spin Velocity

5. LABORATORY QUALITY SYSTEM REQUIREMENT

The laboratory performing the procedures specified in this document 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.

[3] 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.

6. APPARATUS

The required apparatus consists of a test machine with a round test surface capable of rolling test tires at the velocities defined in the test conditions, Section 10.3 Test Speeds. The test surface shall allow mounting of test cleats one at a time, as specified in this practice. The machine shall have an instrumented spindle capable of measuring three forces ($F_{X''}$, $F_{Y''}$, and $F_{Z''}$) and two moments ($M_{X''}$ and $M_{Z''}$) developed during tire impact with a test cleat. The instrumentation also measures tire angular displacement, Φ, using absolute encoders. Figure 3 is a schematic of such a machine. Appropriate data-acquisition equipment is considered to be part of the apparatus. The space housing the loading machine is also considered to be part of the apparatus.

Vibration initiated by the tire/cleat impact process and outside sources is so important in this document that vibration requirements are discussed explicitly in Section 6.1, the first subsection in this part of the practice.

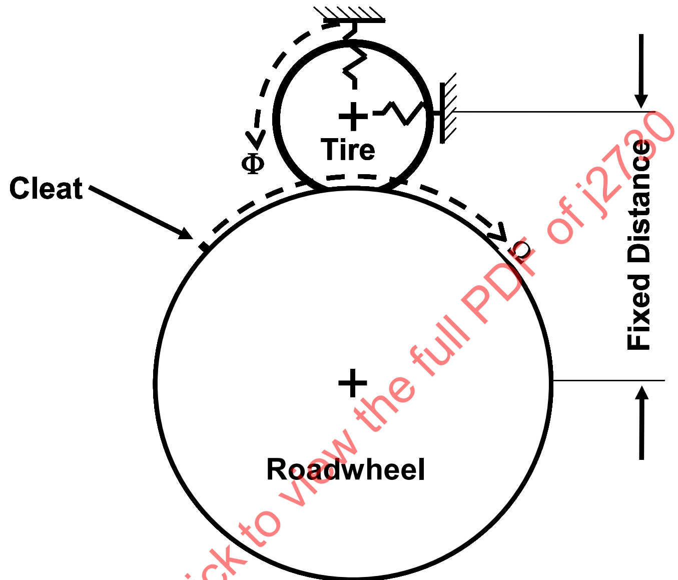

FIGURE 3 - TEST MACHINE SCHEMATIC[4]

6.1 Environmental Vibration and Isolation

Tire/cleat impact in the case of a rigidly constrained spindle, as is used in this test, generates very significant dynamic forces. The instrumented spindle will respond to force signals regardless of whether they reach it directly from the tire/wheel system, as is desired, from the test surface through the machine frame, or from a source in the laboratory environment through the floor and then the machine frame.

The machine's planned environment should be tested for significant structure borne vibration arising from the laboratory environment prior to installation.[5] If no such vibration is found, the machine can be mounted on a normal foundation. If significant, environmentally-associated, vibrations are discovered, two courses are open. The first is to ascertain whether or not there are predictable periods when the environmental vibrations are at a low enough level to permit testing. Is there enough usable time to permit adequate machine use? If enough usable time exists, an operational schedule adjustment may resolve the problem. If scheduling can't mitigate the problem, a second course is as follows, an adequate vibration isolated machine foundation should be designed by a machine isolation expert, and the cleat impact machine installed on it. In very bad cases both isolation and scheduling may have to be pursued. In any case, environmental vibration monitoring should continue during machine use to warn of environmental changes that may affect test results.

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[4] An external drum machine is shown, as an example. An internal drum machine is also acceptable.

[5] Significance is a judgment that should be made by a competent expert in machine isolation.

Structural resonances are an inherent feature of test machines. Depending on their frequencies machine resonances can lead to serious distortions in the measured data. Figures 4 and 5 show an example of amplitude and phase distortion due to a machine resonance. Ideally, all machine resonances should be at frequencies, at least three times the expected first natural frequencies of the tires, which a machine is designed to test.[6] However, this may not be possible.[7] Thus, it is recommended that the test machine be evaluated for resonances while mounting a metal part, the inertia surrogate, simulating the mass and inertia of the most massive tire/wheel assembly to be tested.[8] Machine evaluation with the surrogate mounted, as discussed below, will identify lowest machine resonances and give a feeling for the fraction of the test results arising from transmission of cleat impact forces from the test surface through the machine frame back into the load cell, transmission through the back path.

Once the machine resonances and back path transmission are known, the engineer has the option of using the machine data, as is, while bearing its limitations in mind, or employing Dynamic Force Measurement System (DFMS) technology, SAE 2001-01-0790, or a related technology to eliminate spurious responses.[9] It is good practice to choose an option during the machine design phase or in prototype testing for reasons of economics and delay.

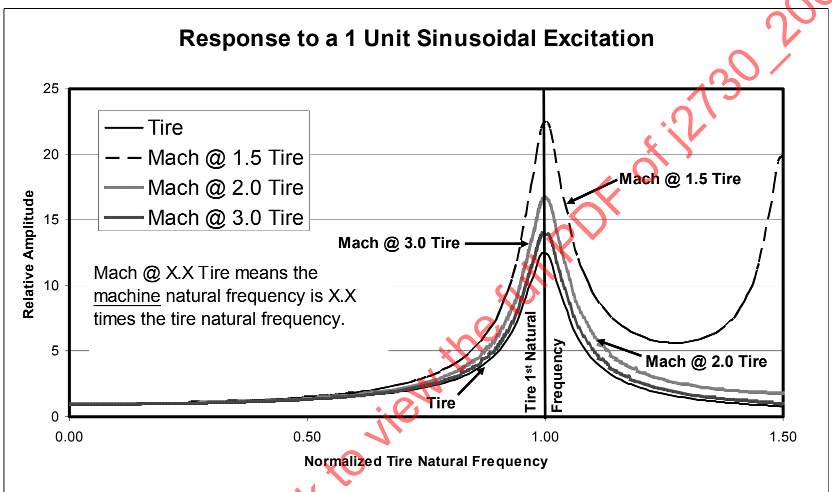

FIGURE 4 - ILLUSTRATION OF THE AMPLITUDE EFFECT OF A MACHINE RESONANCE

6 Each of the measured forces and moments will have an associated set of natural frequencies. From Task Force's viewpoint the first natural frequency in each case will probably be the crucial one.

7 Exact minimum machine resonant frequency recommendations are not made in this Recommended Practice. This was done for two reasons. First, this practice is applicable to all tires regardless of size (wheelbarrow to earthmover) so a single answer is inappropriate. Second, evolving tire designs may alter the required frequencies.

8 A disc with a thick outer edge can be used to produce the mass and inertia simulation. The required mass and inertia values can be determined by applying SAE J2717 to the most massive tire/wheel assembly likely to be tested.

9 DFMS technology uses accelerometer data derived by instrumenting the spindle assembly to correct results for inertial forces and moments, which occur due to the physical design of the test machine and its measuring head.

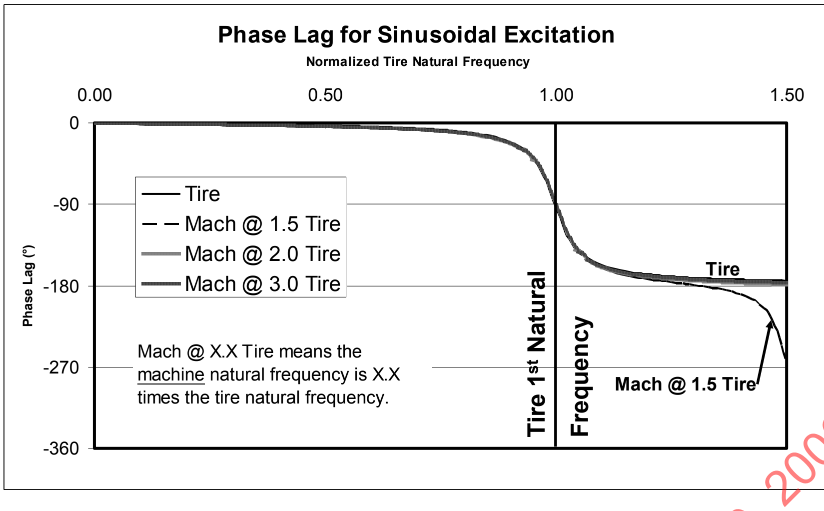

FIGURE 5 - ILLUSTRATION OF THE PHASE EFFECT OF A MACHINE RESONANCE

6.1.1 Machine Resonance Evaluation

With the inertia surrogate mounted on the machine, but not in contact with the test surface, a modal impact hammer is used to selectively strike the surrogate while recording the outputs of the hammer's load cell and of the load cells on the instrumented spindle. The transfer functions are evaluated using a spectrum analyzer.[10] The resultant outputs show the relevant natural frequencies and give a picture of machine crosstalk under dynamic conditions. There are five impact experiments required assuming that the analyzer can deal with six or more channels of simultaneous signals. If fewer channels are available, then each impact experiment will have to be broken into a series of separate experiments. The experiments are defined in the subheadings of this section. In each experiment, it is good practice to repeat the impact four or more times and average the results. Each experiment is performed with the loading system clamps in their locked position. These clamps are noted in Section 6.2. These experiments only need to be performed when the machine is first placed in service or if a major modification is made to the machine.

In the machine characterization experiments, the force applications should be lined up as perfectly with their defined orientations as possible and applied as near their ideal application locations as possible. Angular misalignment of a force application will input forces in two or more directions instead of one. For example, an input of $F_{Y''}$ at a small angle to the Y"—Axis instead of parallel to it will indicate that the machine measures the wrong amount of force in other directions when the input is $F_{Y''}$. That is, the apparent crosstalk, for example, $F_{X''}/F_{Y''}$ will not be correct. Locational force application errors lead to unexpected or distorted moment applications and more crosstalk errors. If errors of the type just discussed exist, the crosstalk matrices will be in error and the machine measurements will be in error.

10 Note that force/force, force/moment, moment/force, and moment/moment transfer functions all occur in the course of the set of frequency response experiments.

6.1.1.1 Lateral Force Impact

The inertia surrogate is struck as indicated in Figure 6. By striking in line with the Y"—Axis the only input is a pulse of lateral force, $F_{Y"}$.

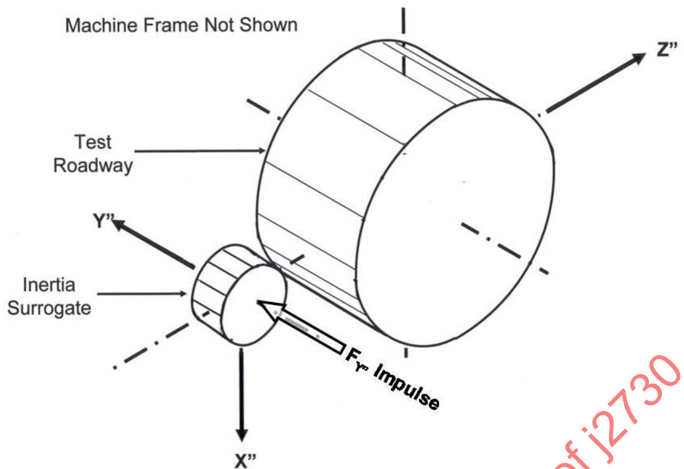

FIGURE 6 - INPUTTING AN $F_{Y"}$ IMPULSE WITH A MODAL HAMMER

6.1.1.2 Longitudinal Force Impact

The inertia surrogate is struck as indicated in Figure 7. By striking in line with the X"—Axis the only input is a pulse of longitudinal force, $F_{X"}$.

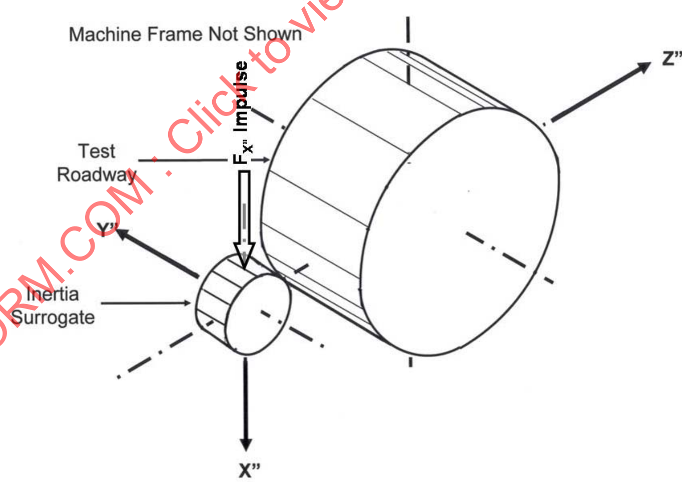

FIGURE 7 - INPUTTING AN $F_{X"}$ IMPULSE WITH A MODAL HAMMER

6.1.1.3 Normal Force Impact

The inertia surrogate is struck as indicated in Figure 8. By striking in line with the Z”—Axis the only input is a pulse of normal force, $F_{Z''}$.

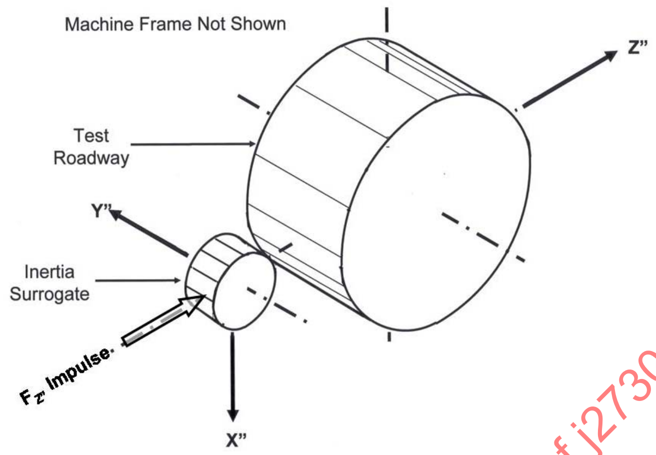

FIGURE 8 - INPUTTING AN $F_{Z''}$ IMPULSE WITH A MODAL HAMMER

6.1.1.4 Overturning Moment and Lateral Force Impact

The inertia surrogate is struck as indicated in Figure 9. By striking at the center of the surrogate’s flange in line with the Z”—Axis and parallel with the Y”—Axis both a pulse of lateral force, $F_{Y''}$, and a pulse of overturning moment, $M_{X''}$ are generated. The effect of the $M_{X''}$ input is obtained by comparing the output of the $F_{Y''}$ experiment, Section 6.1.1.1, with the results of this experiment.

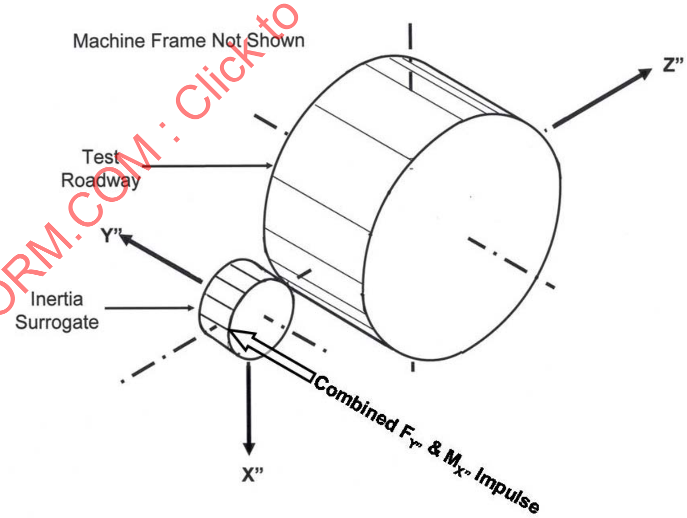

FIGURE 9 - INPUTTING BOTH $F_{Y''}$ AND $M_{X''}$ IMPULSES WITH A MODAL HAMMER

6.1.1.5 Aligning Moment and Lateral Force Impact

The inertia surrogate is struck as indicated in Figure 10. By striking at the center of the surrogate's flange in line with the X"—Axis and parallel with the Y"—Axis both a pulse of lateral force, $F_{Y"}$, and a pulse of aligning moment, $M_{Z"}$, are generated. The effect of the $M_{Z"}$ input is obtained by comparing the output of the $F_{Y"}$ experiment, Section 6.1.1.1, with the results of this experiment.

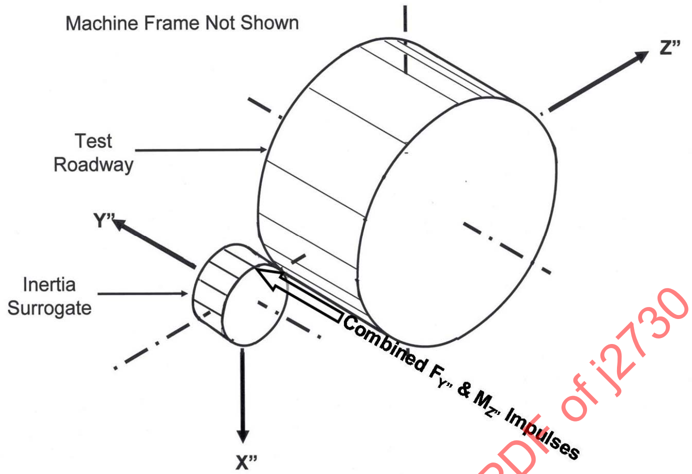

FIGURE 10 - INPUTTING BOTH $F_{Y"}$ AND $M_{Z"}$ IMPULSES WITH A MODAL HAMMER

6.1.2 Back Path Transmission Evaluation[11]

With the inertia surrogate mounted on the spindle, but not in contact with the test surface, and the loading system clamps noted in Section 6.2 in their locked position, the five experiments described in the subheadings of this section are to be performed. Record the output from both the hammer's load cell and the load cells of the instrumented spindle. The transfer functions are evaluated using a spectrum analyzer. The resultant outputs give a picture of back path transmission under dynamic conditions. In these experiments it may be necessary to use a heavier modal hammer than that employed in Section 6.1.1.

[11] If the machine structure is heavily damped or if the back path from the test surface to the spindle contains a mechanical break, the machine may not have appreciable back path vibration transmission.

6.1.2.1 Lateral Force Input into the Back Path

The test roadway is struck as indicated in Figure 11. By striking in line with the Spin Axis of the test roadway the response is equivalent to that to a pure lateral force pulse input to the test roadway.

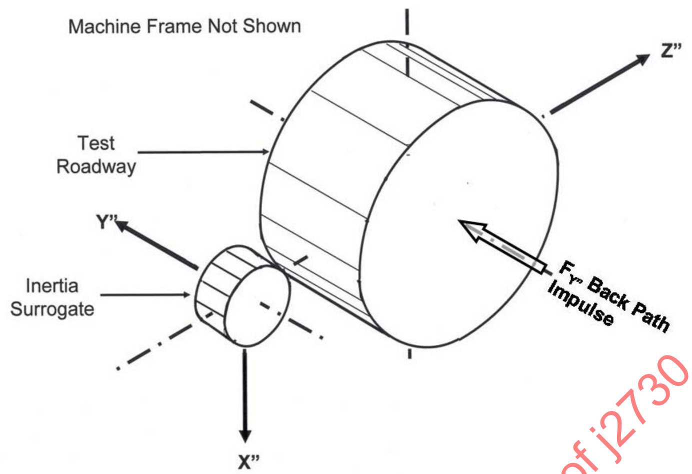

FIGURE 11 - INPUTTING AN $F_{Y''}$ IMPULSE INTO THE BACK PATH WITH A MODAL HAMMER

6.1.2.2 Longitudinal Force Input into the Back Path

The test surface is struck as indicated in Figure 12. By striking at the center of the test surface parallel to the X"—Axis the system response is equivalent to that to a pure longitudinal force pulse input to the test roadway.

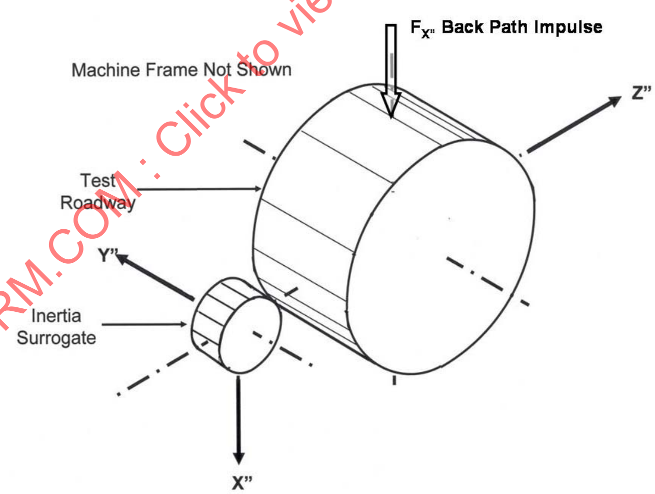

FIGURE 12 - INPUTTING AN $F_{X''}$ IMPULSE INTO THE BACK PATH WITH A MODAL HAMMER

6.1.2.3 Normal Force Input into the Back Path

The test surface is struck as indicated in Figure 13. By striking at the center of the test surface in line with the Z"—Axis the system response is equivalent to that to a pure normal force pulse input to the test roadway.

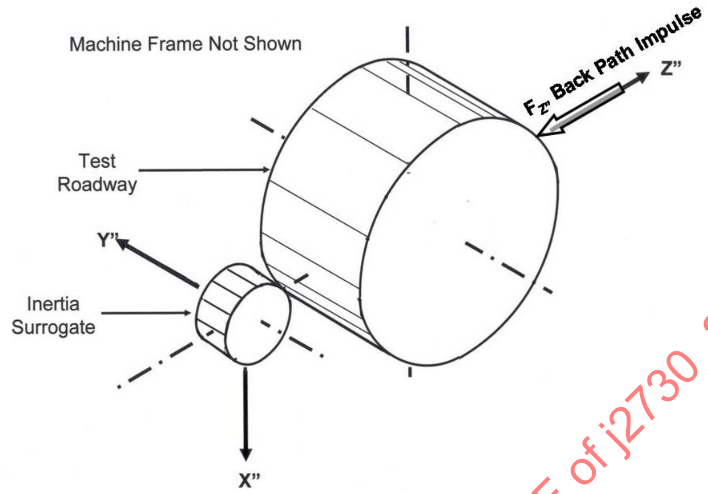

FIGURE 13 - INPUTTING AN $F_{Z''}$ IMPULSE INTO THE BACK PATH WITH A MODAL HAMMER

6.1.2.4 Lateral Force and Aligning Moment Input into the Back Path

The side of test roadway is struck parallel to Y"—Axis in line with the Z"—Axis as indicated in Figure 14. By striking in this way the system response is equivalent to that to simultaneous lateral force and aligning moment pulses. The effect of the aligning moment pulse is obtained by comparing the output of the lateral force pulse experiment, Section 6.1.2.1, with the results of this experiment.

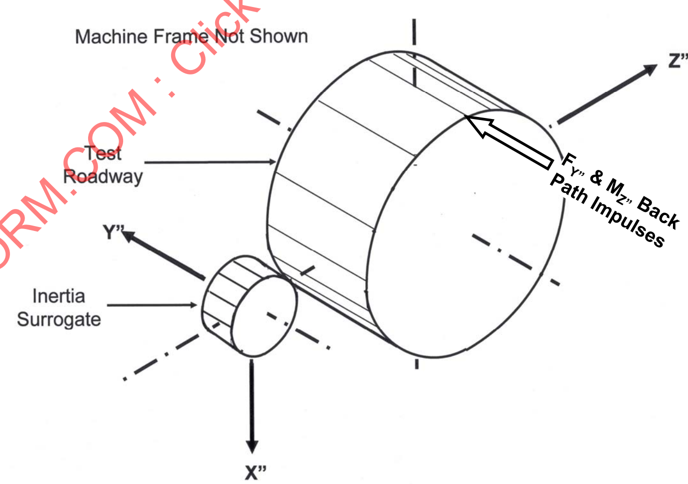

FIGURE 14 - INPUTTING BOTH $F_{Y''}$ AND $M_{Z''}$ IMPULSES INTO THE BACK PATH WITH A MODAL HAMMER

6.1.2.5 Lateral Force and Overturning Moment Inputs into the Back Path

The side of test roadway is struck parallel to Y"—Axis parallel with the X"—Axis as indicated in Figure 15. By striking in this way the system response is equivalent to that to simultaneous lateral force and overturning moment pulses. The effect of the overturning moment pulse is obtained by comparing the output of the lateral force pulse experiment, Section 6.1.2.1, with the results of this experiment.

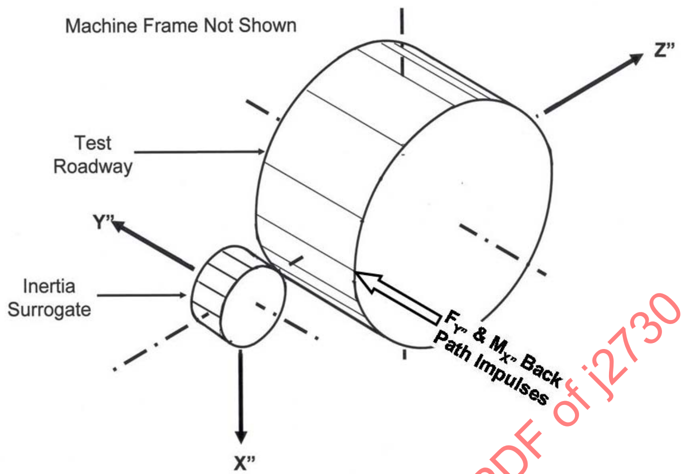

FIGURE 15 - INPUTTING BOTH $F_{Y"}$ AND $M_{X"}$ IMPULSES INTO THE BACK PATH WITH A MODAL HAMMER

6.2 Loading System

The loading system shall maintain the tire at a slip angle of 0° ± 0.05° and an inclination angle of 0° ± 0.05°, common machine specifications when this document was drafted. The system shall be capable of loading the tire to at least twice the 100% load specified by the test requester. It shall be capable of loading the tire to an average normal forces accurate to within ± 1.0% of the test machine's full-scale normal force range when no cleat is mounted and to an average loaded radius accurate to within ± 0.5 mm either with or without a cleat mounted.[12] Loading shall be possible with the test surface either static or rolling.

The loading system must be as stiff as possible during tire/cleat impacts so as to have well defined natural frequencies that are as high as possible given the machine's structure. Backlash in the loading system is highly undesirable and will lower effective stiffness. Therefore, a system of clamps that removes all clearances is a vital feature.[13] This is equivalent to bolting the system fast prior to data acquisition, after the load or loaded radius is set. The clamps must remain in operation during data acquisition, and be released before the load is reset.

So long as the machine's structural design is adequate, it is not important whether the machine is designed such that the Z"—axis is oriented horizontally or vertically.

6.3 Measuring System

6.3.1 Instrumented Spindle

The spindle shall be capable of measuring three forces ($F_{X"}$, $F_{Y"}$, and $F_{Z"}$) and two moments ($M_{X"}$ and $M_{Z"}$). The output shall be corrected for load cell interaction by a matrix method conceptually equivalent to that discussed in SAE J2429. This should be sufficient so long as the structural resonances are well away from the first tire modal frequencies or if DFMS technology has been applied. See Section 6.1.

[12] Due to tire non-uniformity, the normal force and loaded radius vary with tire angular position. Thus, when the tire is rolling the best solution is to set the tire normal force or loaded radius to a value most correspondent to its average value during a tire rotation.

[13] If the clamps work correctly, the loading system will act as a part of the machine's frame during testing.

Load cell sizing must be done on two bases. One is vibration, and the other is force and moment capacity. The larger of the two capacities derived in the subheadings of this section is to be used.

The capacities recommended in this section are best estimates at the time this document was prepared, but are not known to be correct based on experimental evidence.

Force and moment measurements shall be accurate to ±0.5% of each load cell's maximum capacity.

NOTE: A rotating wheel force transducer may be used in place of an instrumented spindle. If this is done, there are several points to verify. 1) Insure that the apparent vertical stiffness of the transducer is constant independent of its angular orientation with respect to the center of tire contact. 2) Determine that the structural resonances of the transducer are well away from the first tire modal frequencies. 3) Insure that the transducer anti-rotate, the member that maintains Φ alignment is stiff enough to prevent a loss of angular reference during the impact event.

6.3.1.1 Vibration Based

Viewing the instrumented spindle as a series of stiffnesses mounted on a rigid foundation supporting the inertia surrogate and any adapters, the machine designer can compute approximate first natural frequencies of the measuring system applicable to the three forces and two moments. Given the expected vibration response of the machine structure, the designer can then decide what load cell stiffnesses are required to achieve the desired frequency response characteristics. In this process there is a decision to be made about magnifaction factors and phase shifts as represented in Figures 4 and 5.

6.3.1.2 Force and Moment Based

The load cell capacities given in Table 2 are believed to be adequate but are best estimates as noted in the last paragraph of Section 6.1. The load cell capacities assume that maximum transient forces are less than or equal to 50% of the steady state load on the tire. The capacities assume that the testing will be conducted such that no contact occurs between the tire tread band and the sidewall/bead area. If such contact occurred, it would be equivalent to cleat-to-wheel crash. This would introduce unknowably high forces damaging the machine, the tire and the test wheel. Section 6.6 contains cautionary information as to what to do to insure that a crash of the type just discussed will not happen during testing. Cell sensitivity, mV/N or mV/N-m, is a balancing consideration in the load-cell choice. It may force a compromise with high natural frequencies.

TABLE 2 - MINIMUM LOAD CELL CAPACITIES BASED ON FORCE AND MOMENT

Force or Moment	Load Cell Capacity
Longitudinal Force	-(Maximum 100% Tire Load[14]) ≤ $F_{X''}$ ≤ (Maximum 100% Tire Load)
Lateral Force	-(Maximum 100% Tire Load) ≤ $F_{Y''}$ ≤ (Maximum 100% Tire Load)
Normal Force	-(300% Maximum Tire Load) ≤ $F_{Z''}$ ≤ 0
Overturning Moment	-$F_{Y''}$ Capacity times R_{lmax} ≤ $M_{X''}$ ≤ $F_{Y''}$ Capacity times R_{lmax}[15]
Aligning Moment	-$F_{Y''}$ Capacity times R_{lmax} ≤ $M_{Z''}$ ≤ $F_{Y''}$ Capacity times R_{lmax}

NOTE: By way of example, assume that the machine in question was designed to test tires with 100% loads up to 9000 N with a maximum loaded radius in test of 0.4 m. That would mean that the load cell capacities would need to be as follows.

14 The maximum 100% tire load is the 100% load for the largest load capacity tire the machine is designed to test.

15 R_{lmax} is the largest expected loaded radius that will occur during testing.

TABLE 3 - LOAD CELL CAPACITY EXAMPLE

Design Load Cell Capacity Example	
Force or Moment	Load Cell Capacity
Longitudinal Force	$-9000\ N \le F_{X''} \le 9000\ N$
Lateral Force	$-9000\ N \le F_{Y''} \le 9000\ N$
Normal Force	$-27\ 000\ N \le F_{Z''} \le 0$
Overturning Moment	$-3600\ N\text{-}m \le M_{X''} \le 3600\ N\text{-}m$
Aligning Moment	$-3600\ N\text{-}m \le M_{Z''} \le 3600\ N\text{-}m$

6.3.2 Loaded-Radius Instrumentation

The system shall measure loaded radius over a range from at least 0.8 times the flange radius of the smallest wheel that is expected to be mounted up to 1.2 times the unloaded crown radius of the largest tire expected to be tested. The measurement shall be accurate within ± 0.5 mm.

6.4 Data Acquisition

Data may be acquired either time sampled or spatially sampled, based on test roadway angular position.

6.4.1 Time Sampled

Test data for all channels shall be simultaneously sampled at a minimum rate of 2000 samples per second. Analog anti-aliasing filters with a corner (–3 dB) frequency set to 25% or less of the sampling frequency shall be utilized in the data acquisition system. The filters shall be four pole or higher.

Depending on specific data reduction methods, algorithms, and requirements, the data can either be sampled continuously during a series of revolutions of the test roadway, or individual datasets, one for each cleat impact, can be recorded. If sampling continuously, a pulse signal, indicating a reference position of the test roadway with respect to the test tire, shall be recorded simultaneously with the other data channels. If recording individual datasets, the data acquisition for each revolution of the test drum shall be triggered at a test drum angular position at least 50 mm before the test cleat first encounters the tire. Data acquisition for a revolution will be terminated prior to the trigger for the next revolution. Either method shall allow acquisition of a predetermined number of individual data sets.

6.4.2 Spatially Sampled

Test data for all channels shall be acquired at a rate corresponding to 5 mm in traveled distance or less.[16] Data shall be simultaneously sampled and held. Analog anti-aliasing filters with a corner (–3 dB) frequency set to 25% or less of the sampling frequency applicable at the lower test speed shall be utilized in the data acquisition system. The filters shall be four pole or higher.

Data acquisition for each revolution of the test drum shall be triggered at a test drum angular position at least 50 mm before the test cleat first encounters the tire. Data acquisition for a revolution will be terminated prior to the trigger for the next revolution. The system shall allow acquisition of a predetermined number of individual data sets following issuance of an initiation pulse.

6.5 Test Surface

The test surface shall be a bare metal drum. A well designed metal drum can provide adequate speed capability, a good foundation for cleat attachment, and contribute to proper machine natural frequency behavior (see Section 6.1) while avoiding undesired inputs due to test surface radius errors. The drum diameter shall be 1.7 m or more.

16 This corresponds to time sampling at about 1790 Hz at the lower of the two test speeds specified in Section 10.3 and at approximately 3600 Hz at the higher of the two speeds.

NOTE: 1.7 m drums are common. The tire oscillations due to cleat impact during the test should die out for passenger tires prior to a second encounter with a cleat at speeds of 64.4 km/hr or less as specified in Section 10. However, a large, low pressure tire may not become quiescent within a single revolution of a 1.7 m drum, thus, this should be checked prior to choosing a drum diameter during the machine design process. Further, tire natural frequencies are tire test drum diameter dependent. It is also possible that amplitude is test drum diameter dependent. For convex drums, ones on which tire contact occurs on the outside of the drum, tire natural frequencies drop as the drum diameter becomes larger with the lowest frequencies occurring on a flat surface.

6.6 Test Cleats

The purpose of the cleats is to excite a nonlinear dynamic tire response to an impulse type excitation occurring due to enveloping at driving speeds. The tire modes are expected to be excited simultaneously with large deformations of the tire comparable to those encountered during travel on a rough surface. A recommended cleat cross section for passenger and light truck tires has a square cross section 15 mm X 15 mm with a 2 mm bevel on the corners, Figure 16. This cleat cross section may not be adequate for users who wish to test larger tires. They will typically need cleats with a larger cross section.

NOTE: The Task Force, which is a temporary entity organized by the Vehicle Dynamics Standards Committee, does not have evidence as to a proper cleat size for TBR, farm or OTR tires, but its engineering judgment is to begin experiments to determine a proper cleat on the basis given in the note at the end of this section. If those developing cleats for TBR, farm and OTR tires will share their results with the Vehicle Dynamics Standards Committee, the next revision of this document will contain specific recommendations for cleat sizing to use with larger tires.

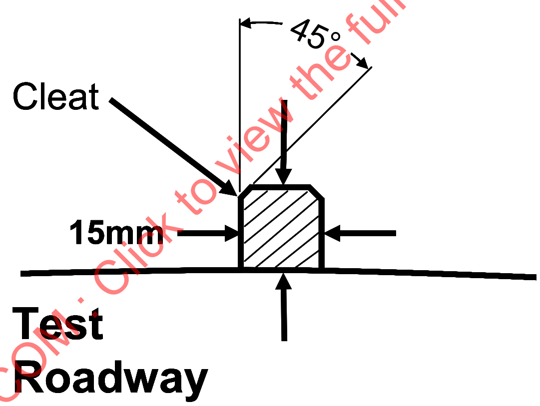

FIGURE 16 - CROSS SECTIONAL VIEW OF MOUNTED 90° CLEAT

Test cleats must fasten to the drum surface so as to prevent bending parallel to the surface of the test drum. This requires fastening the cleats to the surface not only at the edges of the surface, but also in the middle.

To prevent rocking, and to provide a firm foundation, the cleats must conform to the curvature of the test surface as illustrated for the 90° cleat in Figure 16. On drums this requires cleats with alternative crest angles to have double curvature to insure firm mounting. That is, cleats whose crest angle is not 90° must twist around the test surface like a helical gear tooth.

When testing low aspect ratio tires, a certain amount of cautious preliminary experimentation with cleat size and tire load may be required to insure that the cleats used will not lead to damage to the test wheel.