



Wheel Rotary Bending Fatigue Test

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 is intended to provide details for determining the fatigue strength of Body Frame Integral (BFI) car or sport utility vehicle wheels and Body On Frame (BOF) mid-size or full size pickup, or sport utility vehicle, wheels during dynamic rotary bending of the wheel disc sustained during vehicle cornering maneuvers.

1.1.1 Method A. Applies to steel road wheels for use on BFI car or sport utility vehicles.

1.1.2 Method B. Applies to aluminum and steel road wheels for use on BOF mid-size or full size pickup, or sport utility vehicles, and aluminum and steel compact temporary use wheels for use on BFI and BOF vehicles.

1.1.3 Method C. Not to be specified for new programs.

1.1.4 Method D. Applies to aluminum road wheels for use on BFI car or sport utility vehicles.

1.2 Applicability. This test procedure is applicable for steel and light-alloy wheels intended for normal highway use and temporary use for BFI car or sport utility vehicles, BOF mid-size or full size pickup, or sport utility vehicles including dual wheel usages, or multipurpose vehicles.

1.3 Remarks.

1.3.1 This procedure establishes a uniform testing technique that assesses dynamic wheel fatigue due to rotating bending forces applied to the wheel disc for the purpose of evaluating wheel design conformance to specifications. The technique is based on methods listed in Table 1.

Table 1: Wheel Fatigue Technique Documents

Identification Number	Title (English)	Native Country (if Regulatory)
ABNT NBR 6752	Aluminum Alloy Wheels for Light Commercial Automobiles and SUVs - Performance Verification Tests	Brazil
IS-9436	Wheel Rims - Performance Requirements and Methods of Tests	India
SNI 1896	Wheel Rim for Vehicle Category M, N and O	Indonesia
COVENIN 363/97	Steel Wheels for Passenger Cars	Venezuela
COVENIN 3736/02	Aluminum Wheels for Passenger Cars	Venezuela
UN R124.00 Supplement 1	New Replacement Wheels	Europe
GB/T 5334	Performance Requirements and Test Methods of Passenger Car Wheels	China

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Identification Number	Title (English)	Native Country (if Regulatory)
Association of European Wheel Manufacturers (EUWA) ES 3.18	Test Requirements for Temporary-use Spare Wheels for Cars	Europe
Article 09, TRIAS 09-J002-001	Running System (Wheels and Tires)	Japan
StV 13/36.25.07-20.01	Guidelines for the Testing and Inspection of Custom Wheels for Motor Vehicles and their Trailers	German
ISO 3006	Road Vehicles – Passengers Car Wheels for Road Use – Test Methods	Not applicable
ISO 3894	Road Vehicles – Wheels/Rims for Commercial Vehicles – Test Methods	Not applicable
SAE J267	Wheels/Rims – Truck and Bus – Performance Requirements and Test Procedures for Radial and Cornering Fatigue	Not applicable
SAE J328	Wheels – Passenger Car and Light Truck Performance Requirements and Test Procedures	Not applicable
SAE J1992	Wheels/Rims – Military Vehicles – Test Procedures and Performance Requirements	Not applicable
SAE J2530	Aftermarket Wheels - Passenger Cars and Light Truck - Performance Requirements and Test Procedures	Not applicable

1.3.1.1 A fully processed wheel is securely held in a fixture by either or both rim flanges and is mounted through an adapter plate to the load arm shaft. The test equipment shall be designed to enable a constant moment of rotating bending load to be exerted via the hub mounting surface onto the wheel's disc.

1.3.1.2 Currently, within the industry there are two (2) rotating bending machine designs.

- Stationary wheel is subjected to a rotating bending moment applied by the load arm shaft (Stationary Wheel).
- Fixture rotates the wheel under the influence of a stationary bending moment (Rotating Wheel).

1.3.1.3 The deflection of the load arm shaft is continuously measured, and when a preset deflection value is obtained the test is stopped. If a deflection shutdown does not occur, the test is suspended at a GM specified number of operational cycles.

Note: Preset deflection value is a multiple of the initial deflection value measured at less than 5000 operational cycles (e.g., 110% implies a 10% allowable deflection growth before test termination).

1.3.2 GM Regional Changes. It should be noted that all GM Regions are to use Methods A through D as prescribed in 1.1.1 through 1.1.4. Prior test loads, cycle requirements and sample sizes were called out dependent on the particular region as listed.

- Method A: GME and GM Holden.
- Method B: GMNA, GMK and PATAC.
- Method C: GMB.
- Method D: Not specified.

Note: This is to be used as information only, not for current practices.

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2 References

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

2.1 External Standards/Specifications.

ABNT NBR 6752	EUWA ES 3.18	ISO 3894	SAE J2530
Article 09, TRIAS 09-J002-001	GB/T 5334	SAE J267	SNI 1896
COVENIN 363/97	IS-9436	SAE J328	StV 13/36.25.07-20.01
COVENIN 3736/02	ISO 3006	SAE J1992	UN R124.00 Supplement 1

2.2 GM Standards/Specifications.

GMW16590	GMW17088	GMW17097
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2.3 Additional References.

GM Wheel Drawings (ID)

(ID) = These documents are limited to internal distribution within General Motors and shall not be distributed outside this company. Contact the GM Lead Engineer for further instructions.

3 Resources

3.1 Facilities. Roofed facility that ensures equipment does not deteriorate between calibration events.

3.2 Equipment.

3.2.1 Zyglo or equivalent dye penetrant crack inspection media.

3.2.2 Various hand tools as required, examples listed in 3.2.2.1 and 3.2.2.2.

3.2.2.1 Torque wrench capable of applying and measuring requested torque values. Torque measurements shall be accurate within $\pm 3 \text{ N}\cdot\text{m}$ ($\pm 2.2 \text{ lb}\cdot\text{ft}$).

3.2.2.2 Paint pens as needed; refer to 4.3.6.7 for required colors.

3.2.3 A test machine approved by GM such that either the stationary wheel is subjected to a rotating bending moment or the wheel rotates under the influence of a stationary bending moment.

3.2.3.1 Stationary Wheel. Machine incorporates a stationary mounted wheel and is capable of applying constant loading moment utilizing an eccentric rotating mass for speed control. Refer to Figure 1.

3.2.3.2 Rotating Wheel. Machine incorporates a mounted rotating wheel and is capable of applying constant loading moment that is exerted by a stationary force applied to a rotating loading arm. Refer to Figures 2 and 3.

3.2.3.3 Bending moment is generated by a force applied perpendicular to a load arm shaft by means of a bushing (or bearing) at a distance of $900 \text{ mm} \pm 150 \text{ mm}$ ($36 \text{ in} \pm 6 \text{ in}$) from the hub mounting surface of the wheel.

3.2.3.4 A system for continuously controlling applied load value accurate within $\pm 2.5\%$ ($\pm 3\%$ for tests on light truck wheels intended to be used as dual wheels).

3.2.3.5 A system for continuously measuring shaft deflection values accurate within $\pm 2\%$.

3.2.3.6 A system for controlling the machine speed or shaft rotational velocity below the resonant frequency of the machine's load path.

Note: Stationary Wheel Test Machine. Add mass to slow the rotational speed of the load arm.

Note: Rotating Wheel Test Machine. Historically, rotating wheel machines have a constant (non-varying) speed. Two (2) typical industry speeds are: $350 \text{ rpm} \pm 50 \text{ rpm}$ and $500 \text{ rpm} \pm 50 \text{ rpm}$. However, there are a small percentage of variable speed machines within the industry, having an approximate maximum speed capability of 750 rpm .

3.2.3.7 A system for counting test cycles only when test load is applied.

3.2.3.8 A system that will stop counting test cycles, remove test load, and stop machine rotation at a predefined cycle count or shaft deflection limit.

3.2.3.9 Adapters for specified fastener sizes and bolt patterns. An adapter is a removable plate that retains serrated shank wheel bolts or internally threaded hub member, and attaches to a load arm shaft. An adapter can have one (1) or more bolt hole patterns. The pattern of adapter bolt hole centers shall be in true position relative to the wheel mounting surface and the rotational center of the load shaft, regardless of feature size, within 0.06 mm (0.002 in).

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3.2.3.10 Wear Plate (optional for aluminum wheels). This is a hardened steel plate that is mounted between the test wheel and the adapter. If a wear plate is not used, then the adapter shall be single bolt pattern with a surface condition matching the wear plate specifications.

Note: The wear plate provides a hard, smooth, clean surface for mounting the test wheel. Typical stock used is 6.35 mm ($\frac{1}{4}$ in) AISI 4142 Flat Ground Stock that is a modified pre-hardened Decarburization Free (DCF) alloy steel: 0.2 m wide $\times$ 0.9 m long (8 in wide $\times$ 36 in long), SAE International (SAE) 6150 steel or equivalent material with hardness between 28 Hardness Rockwell C (HRC) and 50 HRC scale, having a thickness of $5 \text{ mm} \pm 1.5 \text{ mm}$ ($0.197 \text{ in} \pm 0.060 \text{ in}$) with both surfaces parallel within 0.2 mm (0.008 in) with an initial surface finish of 1.6 μm maximum. The wear plate shall be free of paint, dirt, or foreign matter.

Note: Generally wear plates are initially manufactured at the maximum thickness allowed and may be reused until indentations can be felt with a finger. At that time, they should be resurfaced or discarded.

3.2.3.11 Clamping elements for securing the wheel to the machine, as needed.

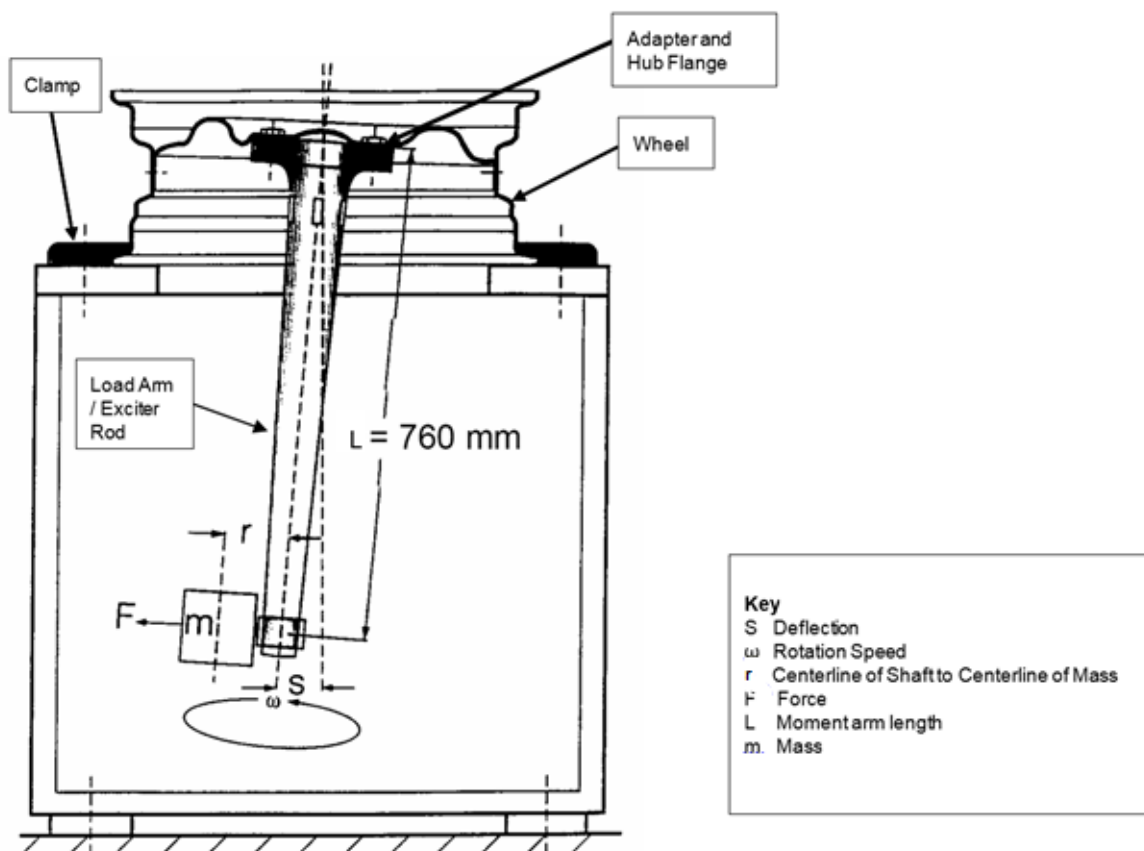


Figure 1: Stationary Wheel – Rotary Bending Fatigue Test Machine Design

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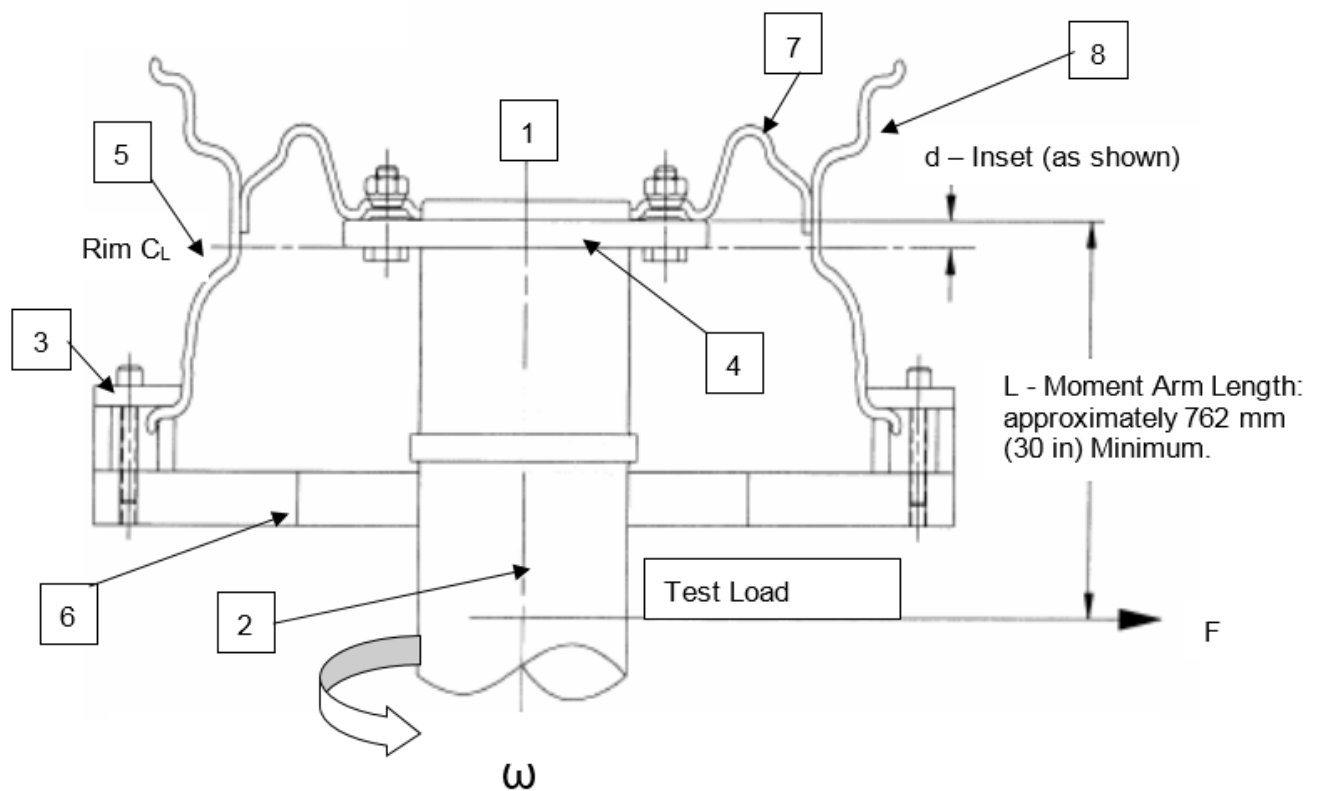
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- 1 Pivot Point
- 2 Loading Arm
- 3 Wheel Fastener (Fixture)
- 4 Adapter
- 5 Rim Center Plane
- 6 Rotary Disc
- 7 Wheel Disc
- 8 Wheel Rim

F Load
 d Inset
 L Moment Arm
 ω Rotation Speed

Note: Moment arm may extend above or to the side of the table instead of below table. Refer to Figure 3.

Figure 2: Rotating Wheel - Rotary Bending Fatigue Test Machine Design (Conventional Setup)

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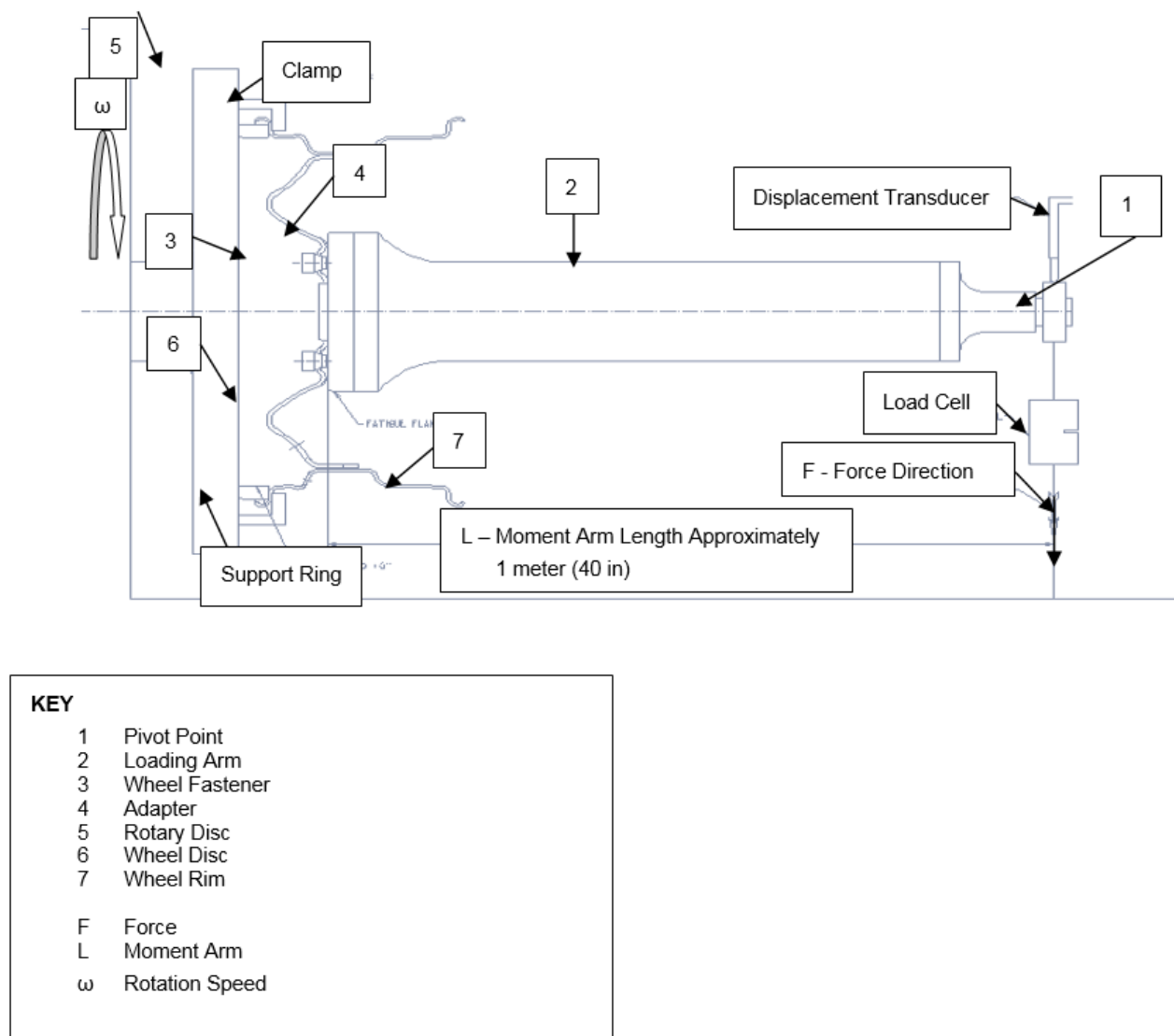


**Figure 3: Rotating Wheel, Rotary Bending Fatigue Test Machine Design
(Conventional Setup – Horizontal or Vertically Above Wheel)**

3.3 Test Vehicle/Test Piece.

3.3.1 Test Wheels.

3.3.1.1 Methods A and C. All wheels shall be fully processed and manufactured to nominal stock thickness conditions, unless otherwise stated by the requester.

3.3.1.2 Method B and D. All wheels shall be fully processed and manufactured to minimum stock thickness conditions, unless otherwise stated by the requester.

3.3.1.3 Aluminum wheels shall not be shot blasted if shot blasting is an optional manufacturing process.

3.3.1.4 Aluminum wheels that are chrome plated shall be tested in the chrome plated condition.

3.3.1.5 Cast, cast flow formed, forged, or forged flow formed aluminum wheels shall not be clear coated or painted, but shall be fully processed, including any paint curing oven events.

3.3.2 Fastener. Production intent wheel attachment fasteners (identified on GM wheel drawings) shall be used, unless otherwise approved by GM.

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3.4 Test Time.

3.4.1 Stationary Wheel Test Machine.

3.4.1.1 Based on Steel Wheels (400 000 + 40 000 Cycles and Five (5) Samples Each).

Calendar time: 5.5 days

Test time: 44 hours

Coordination time: 0.5 hour

3.4.1.2 Based on Steel Wheels (4 000 000 + 400 000 Cycles and Five (5) Samples Each).

Calendar time: 20 days

Test time: 440 hours

Coordination time: 1.5 hours

3.4.1.3 Based on 250 000 Cycles and Nine (9) Samples.

Calendar time: 4 days

Test time: 80 hours

Coordination time: 1.5 hours

3.4.1.4 Based on 1 800 000 Cycles and Six (6) Samples.

Calendar time: 7 days

Test time: 162 hours

Coordination time: 1.5 hours

3.4.2 Rotating Wheel Test Machine.

3.4.2.1 Based on 250 000 Cycles and Nine (9) Samples.

Calendar time: 9 days

Test time: 107 hours

Coordination time: 0.5 hour

3.5 Test Required Information. Test load, fastener torque, chemical composition, mechanical and metallurgical properties, inspection and end of test parameters, per GM wheel drawing or as stated by the requester.

Note: Test load calculations are shown in Sections B1, B2, and B3, Appendix B, if not otherwise specified.

Note: Chemical composition, mechanical and metallurgical properties data are allowed to be supplied by representative samples from the evaluation lot of test materials.

3.6 Personnel/Skills. Test operator shall be qualified on the basis of appropriate education, training, experience, and/or demonstrated skills.

4 Procedure

4.1 Preparation.

4.1.1 Calibration.

4.1.1.1 The bending moment calibration shall be verified as a complete assembled system.

Note: Practical limitations will prevent the system being 100% completely assembled in most cases.

4.1.1.1.1 Preferred Method. The machine bending moment output shall be calibrated versus a known bending moment input (e.g., moment transducer).

4.1.1.1.2 Secondary Method. The machine bending moment load calibration shall be calibrated versus a known linear force input at a known moment arm distance (e.g., load cell transducer).

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4.1.1.2 Calibration of the deflection shutdown system shall be sufficient to ensure machine shutdown when shaft deflection reaches maximum allowed value derived from initial deflection recorded (refer to Sections D1, D2, D3, and D4, Appendix D).

4.1.1.3 The range of load and deflection calibrations shall be large enough to encompass all situations during testing.

4.1.1.4 Machine rotational speed shall be calibrated within 2%.

4.1.1.5 Any additional subsystems that can affect load or cycle life in some manner should be calibrated.

4.1.1.6 Calibration accuracy shall be sufficient to meet the requirements of 3.2.3, unless stated otherwise.

Note: All load cells and displacement transducers used to calibrate the equipment shall be traceable to the National Institute of Standards and Technology (NIST), or equivalent.

4.1.1.7 Equipment calibration shall be performed on a 6 month cycle.

4.1.1.7.1 A maximum of a 1 year calibration interval is allowed if there is at least 5 years of calibration history which shows stable calibration values between calibration events and that operating procedures are in place that ensures machine accuracy during testing. GM test personnel shall review supporting data before allowing annual calibration intervals.

4.2 Conditions.

4.2.1 Environmental Conditions. Room temperature: $24^{\circ}\text{C} \pm 14^{\circ}\text{C}$ ($75^{\circ}\text{F} \pm 25^{\circ}\text{F}$).

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 Refer also to Appendices B, C, and D.

4.3 Instructions. Mount and secure a wheel to a fixture, by either or both rim flanges, and the disc section to an adapter/load arm shaft. The moment is applied by either rotating the wheel under the influence of a stationary bending moment, or a stationary wheel is subjected to a rotating bending moment applied by the load arm shaft. In both cases the deflection of the load arm shaft is continuously measured, and when deflection equals a predetermined multiple of the initial value, the test is stopped. If a deflection shutdown does not occur, the test is continued to a specified number of cycles and suspended (refer to Appendices C and D). In some wheel designs, new and propagating cracks may also end the test.

4.3.1 Select the appropriate wheel adapter, and press or otherwise secure the wheel attachment fasteners into the wheel adapter.

Note: New fasteners shall be used for each test sample.

Note: Wheel attachment fasteners shall be fully seated and perpendicular to adapter surface.

4.3.2 Install appropriate wear plate, as needed.

Note: Either adapter or wear plate, if utilized, shall have an outside diameter that is greater than or equal to the vehicle hub assembly that contacts the inboard side of the wheel disc for the given design.

4.3.3 Mount and secure the wheel adapter to the test machine's load arm/exciter rod.

4.3.4 Mount the wheel to the wheel adapter and install the wheel attachment fasteners.

4.3.4.1 Using a star pattern, tighten wheel fasteners to torque value specified by the requester or wheel drawing. If not specified, tighten to assembly plant minimum dynamic torque specification. Record all observations on the Data Sheet A1, Appendix A.

4.3.4.2 Using a star pattern, recheck fastener torque until requested torque values stabilize.

4.3.5 Machine Instructions.

4.3.5.1 Clamp the wheel to the test machine using appropriate hold-down devices.

4.3.5.1.1 Stationary Wheel. The mass (m) (see Figure 1) shall be selected to achieve a speed of 900 rpm $\pm$ 50 rpm for steel wheels and 1250 rpm $\pm$ 50 rpm for light alloy wheels, given specified test load (M_b).

4.3.5.1.2 Rotating Wheel. Adjust the clamped position of the wheel such that the radial runout of unloaded load arm shaft does not exceed 0.25 mm (0.01 in) Total Indicated Runout (TIR).

4.3.5.1.2.1 Adjust load application (M_b) system to maintain proper moment arm length and to maintain load direction perpendicular to load arm.

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4.3.5.2 If performing Article 09, TRIAS 09-J002-001, record picture of test setup showing the wheel and machine in test configuration.

Note: This may be done at any convenient time. Only one (1) picture is required even when multiple wheel samples are being tested, per each test request.

4.3.5.3 Enter test load value (M_b) into the control system. If appropriate, enter the end of test deflection percentage value into the control system.

Note: Test load (M_b) is stated on the wheel drawing, or otherwise stated by the requester. If the test load is not provided, the calculation is shown in Sections B1, B2, and B3, Appendix B.

Note: Deflection percentage shutdown value is stated by the requester. If the deflection percentage value is not provided, the calculation is shown in Appendix D (Sections D1, D2, D3, and D4).

4.3.5.4 Start machine with:

- Initial load set to zero (0).
- Deflection set to zero (0) at zero (0) load.
- Apply requested load.

4.3.5.5 Adjust Speed. Stop and restart machine to adjust mass which varies the speed, as needed per 4.3.5.1.1, refer to Figure 1.

4.3.5.6 Testing shall not induce resonance vibrations.

4.3.5.7 Methods A, C, and D.

4.3.5.7.1 After a cycle count of 1000, record on Data Sheet A1, Appendix A the wheel deflection and tightening torque (audit torque) of the wheel attachment fasteners. Correct fastener torque as necessary to obtain requested initial torque value derived in 4.3.4.1.

Note: When testing light truck wheels which are intended to be used as duals, use a cycle count of 5000.

4.3.5.8 Method B.

4.3.5.8.1 After a cycle count where the wheel deflection has stabilized, approximately 2000 cycles $\pm$ 500 cycles, record the wheel deflection on Data Sheet A1, Appendix A.

Note: When testing light truck wheels which are intended to be used as duals, record initial deflection and perform audit and re-torque sequence stated in 4.3.5.7.1.

4.3.5.9 Methods A, B, C, and D. Calculate the appropriate deflection shutoff value using formulas stated in Sections D1, D2, D3, and D4, Appendix D, or percentage value stated by the requester. Set the deflection shutdown value into the control system and record on Data Sheet A1, Appendix A.

Note: This process is completed automatically on some machine operating systems.

4.3.5.10 Perform test until end of test criteria (e.g., deflection shutdown, inspection cycle or required number of cycles). Refer to 4.3.7 for end of test criteria.

Note: Refer to Appendices B and C for inspection cycle values, if not stated by the requester.

Note: Refer to Appendix D (Sections D1, D2, D3, and D4) for deflection shutdown percentage values, if not stated by the requester.

Note: Refer to Sections C1, C2, C3, and C4, Appendix C for sample size requirements, if not stated by the requester.

4.3.5.11 Inspect Wheel. Refer to 4.3.6 for inspection process.

4.3.5.11.1 Wheel removal may be necessary for crack inspection; reuse of wheel mounting fastener is acceptable for same sample testing.

4.3.5.12 If not at end of test conditions, per 4.3.7, reinstall wheel and continue testing per 4.3.1 to 4.3.5.11.

4.3.5.13 If testing has reached end of test conditions, per 4.3.7, document test hours and other test data per 4.3.6 on Data Sheet A1, Appendix A. Then repeat testing for additional samples. Refer to Sections C1, C2, C3, and C4, Appendix C for sample size requirements, if not stated by the requester.

4.3.6 Inspection. All wheels shall be inspected for cracks at required inspection intervals and at end of test. Observations shall be documented on Data Sheet A1, Appendix A and on the wheel.

- Verify machine is not operating.

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- Verify load and deflection values are at zero (0) values.

4.3.6.1 Record test cycles and wheel fastener audit torque values, for each attachment fastener on Data Sheet A1, Appendix A.

4.3.6.2 Crack detection media shall be used (e.g., Zyglo or other equivalent dye penetrants).

4.3.6.3 Refer to paragraph 4.3.6.7 for marking wheel cracks on the wheel.

4.3.6.4 Identify wheel cracks on the data sheet per crack location codes stated in Table F1, Appendix F. See also Figure F1, Appendix F for crack location pictorial.

4.3.6.5 If chrome plated wheel exhibits cracking, the chrome plating shall be removed to determine if the crack(s) penetrates base metal.

Note: Care shall be taken when removing chrome plating, such that, the base metal is not adversely affected.

4.3.6.6 Requester shall review all cracks found during wheel inspection.

4.3.6.7 Marking Wheel Cracks.

4.3.6.7.1 Use a fine point marker (paint pen) that will not be removed by materials used during subsequent crack inspections.

4.3.6.7.2 Mark ends of crack with small lines.

4.3.6.7.3 Color code crack marks as in 4.3.6.7.3.1 through 4.3.6.7.3.4.

4.3.6.7.3.1 Black for pretest inspection of light colored wheels.

4.3.6.7.3.2 Yellow for pretest inspection of dark colored wheels.

4.3.6.7.3.3 White for bogie inspection.

4.3.6.7.3.4 Red for end of test inspection.

Note: To describe crack location use the valve stem hole as the zero (0) point, and inspect the wheel in a clockwise direction (looking at the curbside of the wheel). Each spoke and wheel bolt hole position is identified by number with the number one (1) nearest or just clockwise of the valve stem hole and counting upward while traveling in a clockwise direction around the wheel.

Note: Describe crack direction (radial, circumferential, axial, diagonal, etc.) and length.

Note: Describe crack area (window, spoke, support rib, weld, drop well, pocket, curb side, backside, etc.)

4.3.7 Sample, End of Test.

4.3.7.1 When wheel cannot sustain test load.

4.3.7.2 When deflection shutdown occurs.

4.3.7.2.1 Method A, B, and D.

4.3.7.2.1.1 If deflection limit shutdown is due to the first occurrence of a wheel fastener fracture replace all wheel fasteners and continue test. Subsequent fastener fractures will terminate the test.

4.3.7.2.2 Method C.

4.3.7.2.2.1 If deflection limit shutdown is due to a wheel fastener fracture stop testing and proceed to 5.2.5.

4.3.7.3 For All Methods: When chrome plated wheel has documented crack(s) in the base metal.

4.3.7.4 For All Methods: For test suspension cycle values refer to Appendices B and C, if not stated by the requester.

4.3.7.5 Method A.

4.3.7.5.1 When a new or propagating crack is found at minimum stipulated cycles per Table C1, Appendix C, then proceed to 5.2.3.

4.3.7.6 Method B.

4.3.7.6.1 Steel or wrought (fabricated) aluminum wheels:

4.3.7.6.1.1 Review Section C2, Appendix C for crack location requirements.

4.3.7.6.1.2 When a new crack is found at B₁₀ bogie.

Note: Refer to Section B2, Appendix B for B₁₀ bogie value.

4.3.7.6.2 Cast, cast flow formed, forged, or forged flow formed aluminum wheel end of test:

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