



Wheel Bearing Brinelling Resistance and Static Strength

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 standard describes the laboratory procedure for testing wheel bearing brinelling to validate the long-term reliability/durability of wheel bearings used on General Motors passenger vehicles. Wheel bearing suppliers are required to implement their own written procedures that are consistent with, and correlated to, these descriptions.

1.2 Applicability. This standard is applicable for tests performed during product development, Design Validation (DV) and Product Validation (PV) of wheel bearings to be used on General Motors vehicles.

1.3 Remarks. This standard includes a general description of laboratory test procedures for evaluating brinelling (and other issues related to impact strength) of passenger vehicle wheel bearings. Associated measurements, inspections, analyses and monitoring procedures are also given.

The applicable Wheel Bearing Statement of Requirements (SOR) or Component Technical Specification (CTS) provides program specific information and acceptance criteria for bearings tested according to this procedure. In the event there is disagreement between this procedure and the SOR or CTS, the SOR or CTS has precedence.

2 References

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

2.1 External Standards/Specifications.

ISO 1101

2.2 GM Standards/Specifications.

GMW14937 GMW15760

2.3 Additional References.

- Component Technical Specification (CTS)
- Statement of Requirements (SOR)

3 Resources

3.1 Facilities.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.2.1 Test facilities must be certified per the GM Test Improvement Process (TIP).

3.2 Equipment. The test equipment shall be capable of accurately applying the environmental and loading conditions described in this standard. The equipment must be able to apply these inputs at vehicle-specific levels (forces, etc.) and frequencies specified separately by GM for each vehicle program or wheel bearing family. All measurement equipment must be capable of accurately making the measurements specified.

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3.2.1 Fixtures. The fixture for the impact and static load applies should be constructed in similar fashion to the sketch in Figure A1, Appendix A and photographs in Figure B1, Appendix B. A testing correlation between GM and the wheel bearing supplier must be established.

3.3 Test Vehicle/Test Piece.

3.3.1 Parts are specified in this standard for two types of purposes: (1) for determining the reliability/durability of the bearings when exposed to specified customer usage and environmental factors, and (2) additional new (unexposed) parts to be measured or analyzed, in some cases destructively, rather than being exposed to the durability test conditions. Measurements and analyses on these unexposed bearings are used for comparison with parts that have undergone the durability testing. The purpose of these comparisons is to assess potential degradation and/or causes of failure. The additional unexposed parts (henceforth referred to as comparison parts) should be selected from the same sources/batches as the durability test parts.

3.3.2 The brinelling tests should be performed on new parts.

3.3.3 Test parts used for DV are to be from production tooling and processes to the extent possible. PV requires parts to be from production tooling and processes unless an exception is approved in writing by the General Motors contact specified in the SOR document.

3.3.4 Selection of parts undergoing PV shall be made according to GMW15760 Multi-Vari Sample Selection Procedure for Product Validation. The part selection concepts in GMW15760 should also be applied, if possible, during the assembly of components for DV.

3.3.5 Within each phase (DV and PV), the number of test parts for each test shall be at least six (6). During PV, the sample sizes shall be the larger of six (6), or two (2) bearings from each shift (produced a minimum of 3 h apart) on each wheel bearing assembly line (from all assembly facilities). Critical parts (balls or rollers, races, seals, grease, etc.) should come from as many of the planned or actual production sources (suppliers, production lines, shifts, etc.) as possible.

3.4 Test Time.

Calendar time: 10 days

Test hours: 8 hours (per sample)

Coordination hours: 8 hours (per sample)

3.5 Test Required Information.

3.5.1 The supplier is required to have written local procedures consistent with the procedure description in 4.3 of this standard.

3.5.2 There are two main categories of procedures listed in this standard.

- a. Reliability/durability tests, which are simulations of customer usage and environmental exposure.
- b. Inspections, measurements and analyses used to determine the properties and/or condition of new and/or tested bearings.

3.6 Personnel/Skills. Personnel performing the testing and measurements to validate parts for GM shall be trained by the supplier.

4 Procedure

4.1 Preparation. Refer to 4.3 for the test requirements. Build appropriate fixture to position the bearings relative to the machine loading. The supplier's setup and resultant brinell damage must be correlated with GM vehicle-level testing. This can be completed with surrogate bearings that are already in production. A surrogate vehicle can be used with preapproval from GM for the laboratory-to-vehicle correlation.

4.2 Conditions.

4.2.1 Environmental Conditions. All of the bearings are to be tested at normal room temperature, unless otherwise specified.

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.

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4.2.2.1 The brinelling test is intended to find the resistance of the bearing to pothole and curb impact events which can lead to noise. The static strength test is intended to confirm the strength of the bearing when exposed to high lateral loads.

4.2.2.2 The brinelling test is intended to duplicate the results of vehicle-level test GMW14937 Curb Bumping – Lateral Impact. In GMW14937, the vehicle's tire and wheel are impacted laterally by a curb which is attached to (ahead of) a weighted, moving sled. The impact load is measured using piezoresistive load cells, located between the curb and sled. Tests at 5.0 km/h and 8.0 km/h curb impact speeds are normally performed.

4.2.2.3 In the vehicle test, both the vehicle and cart are typically ballasted to the vehicle's Gross Vehicle Mass Rating (GVMR). However, GM may use a different weight, for example, for validating a wheel bearing for multiple vehicle programs.

4.2.2.4 When determining vehicle loads (either by running GMW14937 or analytically), a cast wheel is to be used if the vehicle will have cast wheels as either standard or optional content.

4.2.2.5 The force levels used for the brinelling tests should be derived from an agreed upon vehicle-level test from GM. Data from a surrogate vehicle may be provided by GM if production-intent knuckle design is not available.

4.2.2.6 The GM design engineer and validation engineer will determine quantity of parts to test with and without constant velocity joint (half-shaft). Data with half-shafts is preferable, but corporate common applications may require data without half-shafts.

4.3 Instructions.

4.3.1 Pretest Vibration Measurements.

4.3.1.1 Perform vibration tests on the bearings prior to the loading tests. The pretest vibration levels can be established with comparison parts if the effects of bearing alignment can be corrected and identified. Confirmation that the measured vibration is not related to the 1st and 2nd order alignment of the bearing to the test stand is required if using comparison parts.

4.3.1.2 An accelerometer attached to the bearing housing or load fixture, oriented in the same direction as the radial (vertical) loading, is to be used as the transducer for measuring vibration.

4.3.1.3 The vibration measurements should be made at three different speeds: 400 rpm, 600 rpm, and 950 rpm. Measurements can be performed unloaded or loaded to a level agreed upon by the GM design engineer and validation engineer.

4.3.1.4 Accepted practice is to use frequency-filtered G-Root Mean Square (G-RMS) for characterizing the overall vibration level. Filtering of the raw vibration signal should be done before calculating the G-RMS to prevent extraneous vibrations (e.g., from the fixture or another wheel bearing) from affecting the reading. Frequencies that are most important to keep are the harmonic frequencies that are most closely associated with significant wheel bearing damage. At a minimum, filtering should keep all frequencies that are both (a) above the 4th order of (i.e., four times) the Ball (or roller) Spin Frequency (BSF), and (b) below the 10th order of (i.e., ten times) the Ball (or roller) Pass Frequency for the Inner raceway (BPFI). A high level of vibration between these two frequencies is generally indicative of surface flaw(s) on one or more ball/roller and/or raceway surface. A lower low-frequency cutoff may be used if it can be shown that the lower frequency is used to eliminate a fixture vibration and is still capable of picking up early bearing failures. A band pass frequency can also be used to minimize the effects of bearing runout on the overall vibration levels. The lower band pass should not exceed the 5th order of the rotation frequency.

$$\text{BSF} = \text{PD}/2/\text{BD} \times \text{RF} \times (1 - ((\text{BD}/\text{PD})^2 \times \text{Cos}(\text{CA})))$$

and

$$\text{BPFI} = n/2 \times \text{RF} \times (1 + (\text{BD}/\text{PD} \times \text{Cos}(\text{CA})))$$

Where:

n = Number of balls (or rollers)

BD = Ball (or roller) Diameter

PD = Pitch Diameter (the average of the inner and outer race diameters)

CA = Contact Angle

RF = Rotation Frequency (Hertz)

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Note: BD and PD can be in any units as long as they are the same, since they are used as a ratio.

4.3.1.4.1 It is highly recommended to average the G-RMS readings over a 6 s to 10 s length of time in order to minimize the effect of momentary vibration signals that are not due to wheel bearing damage and to smooth the vibration data. This will minimize momentary spikes in the signal which may occur, for example, during a load or rotation frequency change. Limiting this average to no more than 10 s will ensure that there will be at least one reading with constant load in the shortest step.

4.3.1.4.2 A vibration frequency plot should be recorded.

4.3.2 Load Tests. Wheel bearing samples are to be identified for each load test. The bearing samples should not be used for multiple load tests.

4.3.2.1 Static Load Test. Apply a slow load apply where time to peak load is around 15 s to 20 s. Release the load after approximately 0.5 s to 1 s of hold time. The force and location to apply the force will be provided by GM.

4.3.2.2 Impact Load Test. The laboratory test is to be correlated to the vehicle-level test results, and tunable for different impact loads. An impact test such as that shown in the schematic in Figure A1, Appendix A, is one method of applying the impact load. An alternative is to use a hydraulic ram to apply the load. (The pulse can be approximated as a half-sine wave.) In any case, the fixture must be able to achieve the required load, and to apply the load in a period of time similar to that which would occur in the vehicle test. The time to peak force should be between 20 ms to 35 ms unless otherwise specified. The force and location to apply the force will be provided by GM. Several force levels may be requested.

4.3.3 Strength Test.

4.3.3.1 Fix bearing assembly into test setup similar to static load for brinelling evaluations. Loading position should be at a radius equivalent to the largest available wheel radius. The load should be applied in a lateral inboard direction. A load vs. deflection curve should be generated as the load is applied until the assembly cracks/breaks or the load reaches the value of 7.7 times one-half Gross Axle Weight Rating (GAWR), whichever occurs first.

4.3.3.2 The moment arm bracket must be aligned opposite the top of the wheel bearing's knuckle flange, so the wheel bearing and impact load are oriented the same way as in the vehicle-level curb impact test.

4.3.4 Posttest Evaluations.

4.3.4.1 Vibration Measurements. Perform posttest vibration testing per instructions from 4.3.1.

4.3.4.2 Brinell Measurements. Measure the brinell mark depth at every location of incidence.

4.3.4.2.1 Ball Bearings. Provide geometry and coordinates coinciding with ball contact positions on all wheel bearing races relative to Gross Vehicle Weight (GVW) and 0.5G lateral load at GVW, and half way up the raceway from the contact angle position, and 0.5 mm from edge of race. Descriptions and x-y positions of traces to be provided for each race from a key feature position on the bearing, as well as the diameters from the center of the bearing. Refer to Figures A2 and A3, Appendix A. Perform fourteen (14) measurements at 0.3 mm axial or radial increments, starting 0.5 mm from edge of shoulder.

4.3.4.2.2 Roller Bearings. Establish the span length and initial contact position of roller bearings inboard edge of the roller relative to the centerline of the bearing and provide x and y dimensions to a key feature in the bearing. Measure ten (10) traces along the length of the roller. Refer to Figures A5 and A6, Appendix A.

4.3.4.3 Inspection. Inspect parts for any damage from the load testing.

4.3.5 Inspections, Measurements and Analyses. The supplier is required to conduct failure analyses on all posttest parts, and investigate and understand all indicators of degradation on both failed and non-failed parts, per Table A1, Appendix A. The goal of the analyses is to reduce the rate of degradation through design and/or processes improvements.

Comparison parts are to be obtained at the same time as the parts that will be tested. They should be held in reserve in case they are needed for comparisons with tested parts. If that need does not arise, they may be used for other purposes.

Note: All inspections, measurements and analyses that might be performed on new bearings are described as either Destructive (D) or Non-Destructive (ND) to the wheel bearing assembly. Use comparison parts for all destructive measurements and analyses that are to be performed on new parts.

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4.3.5.1 Dimensional Measurements (ND for parts prior to assembly, D for parts already assembled). Measure and document all dimensions critical to performance of the bearings during the tests. This could include the geometry profiles of the balls/rollers and races, dimensions affecting wheel bearing preload, seal dimensions, etc. Record dimensions prior to and after the durability testing. Document changes and unusual findings during teardown analyses.

4.3.5.2 Surface Roughness (ND for parts prior to assembly, D for parts already assembled). Measure the surface roughness of rolling contact surfaces prior to and after testing (including all damaged surfaces). Measurement may be Root Mean Square Roughness (Rq), Arithmetic Roughness (Ra) or Total Peak-to-Valley Roughness (Rt).

4.3.5.3 Microstructure (D). Examine and document the microstructure of all critical areas of the wheel bearing to ensure proper heat treatment processes and material cleanliness prior to testing. Examine the microstructure of the same areas after testing. Determine the extent, and causes, of all microstructure changes (e.g., the amount of retained austenite before and after testing), and determine the effect of such changes on any failures or degradation that was observed.

4.3.5.4 Case Depth, Hardness Traverse (D). Measure case depth at the rolling contact areas and measure hardness traverse (hardness vs. depth) prior to testing on comparable parts and on at least two posttest parts for each force evaluated once all vibration and brinell depths have been collected.

4.3.5.5 (Posttest) (D) Roundness and Brinell Depth Measurements. Make a polar trace of the surface, to determine brinell mark depth (sectional roundness/flatness Figure A4, Appendix A) at the specified location(s). See Figure C1, Appendix C for example linear plot of the polar trace.

4.3.5.5.1 Brinell Depth Measurement. Make a polar trace of the surface, to determine brinell mark depth at the specified location(s). Apply a filter to the depth trace to establish the sectional roundness/flatness to determine the brinell depth. Preferred filtering on the surface measurements for the brinell depth should be Gaussian with a band pass filter 5 undulations per revolution (upr) to 150 upr. The stylus size used for the trace must also be specified and recommended to be 1 mm diameter or smaller. It is also recommended to use the sectional roundness and/or flatness specification to determine the maximum depth of an individual trace. The data must be recorded at a minimum sample rate of 0.1 degrees. Unfiltered is not preferred. The filter must be set higher than eight (8) times the number of balls or rollers present in a race (150 upr in most cases). The sectional degrees should be the value of 360 degrees divided by two (2) times the number of balls or rollers per raceway.

4.3.5.5.2 Roundness Measurement. Make a polar trace of the surface and apply a filter to smooth the curve to establish the 1st through 5th order effects on roundness. The preferred filtering on the roundness measurements for posttest should be Gaussian with a band pass filter 0 upr to 15 upr. For initial roundness comparisons the trace should be evaluated with a 0 upr to 15 upr filter to look for the 1st through 5th order roundness and a 0 upr to 150 upr filter to look for higher order roundness issues.

5 Data

5.1 Calculations. Not applicable.

5.2 Interpretation of Results.

5.2.1 The maximum brinell depth for each raceway position should be determined from the polar or linear plots. It is recommended to use a sectional roundness and/or flatness to obtain the value and to identify position. The brinell depths should be reported out in a tabular form similar to Tables D1 and D2, Appendix D.

5.2.2 The failure criteria will be given in the Wheel Bearing CTS, and will in general be one or more of the types (5.2.2.1 thru 5.2.2.4) for the brinell test:

5.2.2.1 Noise and vibration observed on a vehicle (as is done with the vehicle-level impact test). This can be on a surrogate vehicle agreed to by GM.

5.2.2.2 Differences in the pre- and post-impact vibration.

5.2.2.3 Brinell mark depth, depending on bearing type.

5.2.2.4 The presence of any abnormal damage caused by the impact loading should also be considered a failure of the part.

5.2.3 The failure criteria will be given in the Wheel Bearing CTS, and will in general be of the type (5.2.3.1) for the static strength test:

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5.2.3.1 Fracture of the bearing assembly.

5.3 Test Documentation. The supplier shall maintain records as listed in 5.3.1 thru 5.3.10.

5.3.1 Written test procedures, including all versions ever used for testing.

5.3.2 A report documenting significant aspects of the initial test development. This would include, as an example, information on any studies conducted to set up details of the test.

5.3.3 All pertinent information about the manufacture and assembly of the wheel bearing assemblies used, including both comparison parts and test parts. This may include, as examples only, the source of all critical parts of each wheel bearing assembly, assembly line and shift information, material specifications, etc.

5.3.4 The results of all inspections, measurements, and analyses.

5.3.5 The results of all tests, including all degradation and failure analyses and data analyses (including the times or cycles to failure, as well as times or cycles at which un-failed parts were suspended).

5.3.6 Actions taken to address issues found on test.

5.3.7 Equipment calibration records.

5.3.8 Any other records deemed necessary for documenting the tests and test results.

5.3.9 The supplier shall provide GM with a report summarizing the parts tested, test conditions, test results, analyses, and follow up actions for each vehicle program or wheel bearing design (if the testing was used to validate bearings for multiple vehicle programs). At a minimum the following (5.3.9.1 thru 5.3.9.7) must be in the brinell test report.

5.3.9.1 The GAWR, Static Loaded Radius (SLR), maximum wheel diameter, and offset used to calculate the loads.

5.3.9.2 Documentation from the test machine of the loads and positions the loads were applied.

5.3.9.3. Documentation of the vibration after test compared to pretest vibration or comparison parts.

5.3.9.4 Tabular results of the vibration and summary of the brinell depths. Supplier is to provide brinell depths for every raceway.

5.3.9.5 All polar traces from which the brinell depth was determined should be included with the sampling rate and filtering used for the trace.

5.3.9.6 Documentation of raceway curvature and hardness of sample parts.

5.3.9.7 Report to be provided in an electronic format, such as a spreadsheet, where the data can be easily analyzed by GM.

5.3.10 At a minimum, 5.3.10.1 thru 5.3.10.3 must be in the static strength test report.

5.3.10.1 The GAWR, Static Loaded Radius (SLR), maximum wheel diameter, and offset used to calculate the loads.

5.3.10.2 Documentation from the test machine of the loads and positions the loads were applied.

5.3.10.3 Photographs of bearings, with any damage highlighted and described.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Notes

7.1 Glossary.

Brinelling: Indentation of the spindle, wheel bearing race(s), or other contact points, caused by a ball or roller, due to a high lateral or radial (typically, impact) load.

Comparison Parts: New parts, taken from the same sources or production batches as test parts that are used for destructive measurements or analyses. These are used for comparison with tested parts at end of test, to determine and understand the extent and cause of any failures or degradation.

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