



Wear Induced Off-Brake Rotor Thickness Variation

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 used to measure the development of wear induced off-brake rotor thickness variation.

It is a laboratory test procedure to measure wear induced off-brake developed rotor thickness variation. The procedure simulates customer off-brake (expressway) driving.

1.2 Applicability. This procedure is applicable to all passenger car and light truck brake corners.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14925 GMW15392

2.3 Additional References.

- Component Technical Specification
- Evaluation Report Template
- Global Document Management System
- Rotor Thickness Variation (RTV) Dynamometer User's Manual

3 Resources

3.1 Facilities. Milford Proving Ground, Brake Component Development (BCD) Rotor Thickness Variation (RTV) dynamometer or equivalent Test Improvement Process (TIP) approved test dynamometer shall be used.

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.

3.2 Equipment.

3.2.1 Dynamometer capable of measuring rotor lateral runout (LRO) and performing static brake applies.

3.2.2 Six non-contact proximity sensors and data acquisition system.

3.2.3 Adapter brackets for installing the rotor and caliper onto the RTV dynamometer shall be produced from production representative brake corner drawings or from measurements made on corner components.

3.2.4 During an inspection cycle, the following measurements shall be made and digitally recorded at 200 Hz:

- Time (s).
- Rotor LRO at inner diameter (ID), center diameter (CD), and outer diameters (OD) of the brake swept area on both the inboard (IB) and outboard (OB) braking surfaces. Refer to Figure A1 in Appendix A.

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- Rotor positional marker voltage (V).

3.2.5 During a static brake apply cycle or a drag torque measurement cycle, the following measurements shall be made and digitally recorded at 50 Hz:

- Brake apply time (month/day/year (mm/dd/yy), hour:minute:second (h:mm:ss)).
- Motor speed (rpm or min⁻¹).
- Left hand (LH) and right hand (RH) caliper brake drag torque, Newton meters (Nm).
- LH and RH rotor IB and OB pad swept area surface temperature, Celsius (°C).
- Maximum caliper experienced pressure, kilopascal (kPa).

3.3 Test Vehicle/Test Piece. Corner assembly consisting of rotor and caliper assembly.

3.4 Test Time.

Calendar time: 8 days
Test hours: 168 hours
Coordination hours: 1 to 2 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. One (1) technician trained in the operation of the RTV dynamometer and capable of performing the duties described in Section 4 is required.

4 Procedure

4.1 Preparation.

4.1.1 The brake corner(s) shall be burnished by performing GMW14925, stopping after the Apparent Piston Travel with Pre-Conditioning section.

4.1.2 The RTV dynamometer load cell(s) shall be calibrated per the RTV dynamometer user's manual.

4.1.3 The brake corner(s) shall be installed using production-representative fastener torque(s) and component spacing. Spacing can be determined through measurements taken from an assembled corner or assembly drawings.

4.1.4 The brake corner(s) is/are to be tested with rotor rotation direction simulating forward vehicle direction of travel.

4.1.5 Brake hose must be in a relaxed position so as to not influence caliper movement.

4.1.6 The RTV dynamometer non-contact proximity sensors shall be calibrated per the RTV dynamometer user's manual. The sensors shall be placed as shown in Figure A1.

4.1.7 All excess air shall be removed from the slide pin boots. The process should be squeezing boot down and lifting the boot edge to allow the air to escape. Slide pin boots shall experience no damage. Boots should not be continuously vented during testing.

4.2 Conditions.

4.2.1 Environmental Conditions. Not applicable.

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.

4.2.3 The mounted rotor LRO shall be $50\text{ }\mu\text{m} \pm 5\text{ }\mu\text{m}$ unless specified otherwise in the Component Technical Specification. Mounted LRO shall be measured at the inboard pad swept area, inboard outer diameter (IBOD) track. LRO adjustment shall be performed by indexing rotors and/or installing a steel shim. An LRO adjustment plate can be used if the RTV dynamometer is so equipped.

4.2.4 Torque measurement load cell(s) shall be zeroed prior to the start of each test sequence while the caliper piston(s) and pads are fully retracted. A load cell is considered zeroed when brake torque reading is $0.00\text{ Nm} \pm 0.05\text{ Nm}$. If the RTV dynamometer is dual-ended, both sides of dynamometer must be zeroed and also be within 0.05 Nm of each other.

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4.3 Instructions.

Note: See Tables A1 thru A3 for complete description of test sections, dynamometer script section numbers, and stop numbers.

4.3.1 Fully retract the caliper piston(s) into the caliper housing.

4.3.2 Fully retract the inboard and outboard pads. Leading and trailing pad ears shall be pulled away from the rotor. The retracted pads shall not touch the rotor.

4.3.3 Perform an Initial Inspection Cycle.

4.3.3.1 Record the six LRO non-contact proximity sensors for 12 s with a motor speed setting of 40 rpm (40 min⁻¹) (allowing for 1 measurement per 1.2 degrees of rotation). IBOD LRO shall be set per paragraph 4.2.3.

4.3.3.2 Repeat paragraph 4.3.3.1 two times for a total of three measurements.

4.3.4 Perform two Pretest Hydraulic Applies.

4.3.4.1 The first apply is 300 kPa $\pm$ 100 kPa for 10 s $\pm$ 2 s and zero rotation. (This apply is done to zero the fluid displacement measurement devices.)

4.3.4.2 The second apply is 500 kPa $\pm$ 100 kPa for 10 s $\pm$ 2 s and zero rotation. (This apply is done to seat the pads against the rotor.)

4.3.5 Perform the First Section of the Main Test (0 h to 7 h Cycle).

4.3.5.1 Perform a static brake apply with brake pressure of 5000 kPa $\pm$ 100 kPa for 10 s $\pm$ 2 s and zero rotation.

4.3.5.2 Start motor at 800 rpm (800 min⁻¹).

4.3.5.3 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure at start of motor.

4.3.5.4 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure starting at 6175 s (two minutes prior to a test duration of 1.75 h).

4.3.5.5 Perform a static brake apply with brake pressure of 5000 kPa $\pm$ 100 kPa for 10 s $\pm$ 2 s and zero rotation at 1.75 h.

4.3.5.6 Start motor at 800 rpm (800 min⁻¹).

4.3.5.7 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure at start of motor.

4.3.5.8 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure starting at 6175 s (two minutes prior to a test duration of 3.50 h).

4.3.5.9 Perform a static brake apply with brake pressure of 5000 kPa $\pm$ 100 kPa for 10 s $\pm$ 2 s and zero rotation at 3.50 h.

4.3.5.10 Start motor at 800 rpm (800 min⁻¹).

4.3.5.11 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure at start of motor.

4.3.5.12 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure starting at 6175 s (two minutes prior to a test duration of 5.25 h).

4.3.5.13 Perform a static brake apply with brake pressure of 5000 kPa $\pm$ 100 kPa for 10 s $\pm$ 2 s and zero rotation at 5.25 h.

4.3.5.14 Start motor at 800 rpm (800 min⁻¹).

4.3.5.15 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure at start of motor.

4.3.5.16 Record drag torque measurement for 125 s with rotor at 800 rpm (800 min⁻¹) and zero apply pressure starting at 6175 s (two minutes prior to a test duration of 7.00 h).

4.3.5.17 Perform an Inspection Cycle.

4.3.5.17.1 Record the six LRO non-contact proximity sensors for 12 s with a motor speed setting of 40 rpm (40 min⁻¹) (allowing for one measurement per 1.2 degrees of rotation).

4.3.5.17.2 Repeat paragraph 4.3.5.17.1 two times for a total of three measurements.

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4.3.6 Repeat paragraphs 4.3.5 (4.3.5.1 thru 4.3.5.17.2) completing with an Inspection Cycle every 7 h (0 to 7, 7 to 14, 14 to 21, 21 to 28, 28 to 35, 35 to 42, 42 to 49, 49 to 56, 56 to 63, 63 to 70, 70 to 77, 77 to 84, 84 to 91, 91 to 98, 98 to 105, 105 to 112, 112 to 119, 119 to 126, 126 to 133, 133 to 140, 140 to 147, 147 to 154, 154 to 161, and 161 to 168).

Note: Do not adjust LRO after initial setup in 4.3.3.1.

Note: Typical test time is 168 h. Test may be terminated by the test engineer for one of the following reasons:

- 168 h have elapsed.
- 125 h have elapsed and thickness variation development has ceased and reached a maximum.
- Less than 125 h have elapsed and the amount of developed RTV is above the upper limit as defined in GMW15392 for brake corner assembly technical specification.

5 Data

5.1 Calculations.

5.1.1 Data Analysis.

5.1.1.1 Raw data is analyzed after implementing a low-pass, digital filter using a 2 Hz cutoff and 0.2 s filter width.

5.1.1.2 Air-gap Thickness. BCD uses capacitive displacement transducers to determine rotor LRO and RTV. These devices measure the distance between the rotor surface and the tip of the displacement transducer (i.e., air-gap thickness). Air-gap thickness is measured in the IB and OB pad swept area at the ID, CD, and OD. BCD is not presently capable of determining absolute rotor thickness with the capacitive displacement transducers. As a result, positional air-gap thickness measurements are used to determine positional RTV. Positional RTV is then used to determine the amount of positional developed RTV at each inspection cycle and at the end of test.

$$\text{Total Air-gap} = [\text{Inboard Air-gap Thickness}] + [\text{Outboard Air-gap Thickness}]$$

5.1.1.3 Rotor Lateral Runout.

IB and OB LRO are determined for ID, CD, and OD locations.

$$\text{Maximum LRO}_{\text{REV}} = (\text{Maximum Air-gap})_{\text{REV}} - (\text{Minimum Air-gap})_{\text{REV}}$$

Where:

REV = revolution

5.1.1.4 Positional Rotor Thickness Variation.

RTV is determined on a positional basis. Refer to Figure A2 in Appendix A.

$$\text{RTV}_{\text{pos}=\text{x}} = (\text{Maximum Total Air-gap})_{\text{REV}} - (\text{Total Air-gap})_{\text{pos}=\text{x}}$$

Where:

REV = revolution; pos = position

Using this RTV equation, zero RTV occurs at the position of minimum rotor thickness. (This position is the same as the position of maximum Total Air-gap.) Additionally, maximum RTV occurs at the position of maximum rotor thickness. (This position is the same as the position of minimum Total Air-gap.)

5.1.1.5 Positional Developed Rotor Thickness Variation.

Developed RTV is determined on a positional basis. Refer to Figure A3 in Appendix A. Positional **Developed RTV** is determined by comparing positional RTV to the start of test positional RTV.

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$$\text{Developed RTV}_{\text{pos}=x, \text{time}=T} = [\text{Maximum (RTV}_{\text{pos}=x, \text{time}=T} - \text{RTV}_{\text{pos}=x, \text{time}=0})_{\text{REV}}] - [(\text{RTV}_{\text{pos}=x, \text{time}=T} - (\text{RTV}_{\text{pos}=x, \text{time}=0}))]$$

Where:

time = 0 = the start of test; time = T = the inspection period; REV = revolution; pos = position

Using this **Developed RTV** equation, zero **Developed RTV** occurs at the position of least rotor wear. Additionally, maximum **Developed RTV** occurs at the position of maximum rotor wear.

5.1.1.6 Calculate the maximum **Developed RTV** at each inspection cycle and the correlating distance traveled for each diameter (ID, CD, and OD).

5.1.1.7 **Developed RTV** determination using absolute rotor thickness measurement. Equations similar to those listed in paragraphs 5.1.1.4 and 5.1.1.5 would be used to determine positional **Developed RTV** when absolute rotor thickness measurements are available.

5.2 Interpretation of Results.

Note: All test results shall be compared to currently released Brake Corner Assembly Technical Specification requirements listed in GMW15392. In the test summary tables, highlight results that do not meet specification requirements.

5.2.1 Graphical Summaries.

5.2.1.1 Graph the RTV vs. rotor position for each inspection cycle for both the left and right corners at the ID, CD, and OD. The RTV for each inspection cycle is determined by averaging the RTV of revolutions 2 through 5. An example graph of RTV vs. rotor position can be seen in Figure A2 in Appendix A. Six graphs shall be reported.

5.2.1.2 Graph the **Developed RTV** vs. rotor position at each inspection cycle for both left and right corners at the ID, CD, and OD. An example graph of **Developed RTV** vs. rotor position can be seen in Figure A3 in Appendix A. Six graphs shall be reported.

5.2.1.3 Graph the maximum **Developed RTV** vs. distance traveled for each diameter (ID, CD, and OD) throughout the entire test. An example graph of maximum **Developed RTV** vs. distance traveled can be seen in Figure A4 in Appendix A.

5.2.1.4 Graph the RTV vs. distance traveled for each diameter (ID, CD, and OD) throughout the entire test. An example graph of RTV vs. distance traveled can be seen in Figure A5 in Appendix A.

5.2.1.5 Graph the Rotor LRO vs. distance traveled for inboard and outboards positions and each diameter (ID, CD, and OD) throughout the entire test. An example graph can be seen in Figure A6 in Appendix A.

5.2.1.6 Graph the brake drag vs. distance traveled throughout the entire test. An example graph of brake drag vs. distance traveled can be seen in Figure A7 in Appendix A.

5.2.2 Tabular Summaries.

5.2.2.1 Create a table listing the maximum **Developed RTV** for side and compare to specification requirements. See example Table A4 in Appendix A.

5.2.2.2 Create a table listing the Rotor Thickness Variation (RTV) vs. distance traveled. See example Table A5 in Appendix A.

5.2.2.3 Create a table listing the Rotor Lateral Runout (LRO) vs. distance traveled. See example Table A6 in Appendix A.

5.3 Test Documentation. Publish the test results using the Evaluation Report template and Global Document Management system or its successor.

6 Safety

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

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7 Notes

7.1 Glossary.

Developed Rotor Thickness Variation: The amount of thickness variation that has developed throughout the course of a rotor thickness variation test. Developed RTV is computed at each measurement position.

Pad Swept Area: Area of rotor braking surface which the brake pads wear during a brake application.

Rotor Thickness Variation (RTV): The difference between maximum total LRO and minimum total LRO during one rotor revolution. Total LRO is the sum of IB and OB pad swept area LRO at each measurement position.

7.2 Acronyms, Abbreviations, and Symbols.

BCD	Brake Component Development
CCD	Chassis Component Development
CD	Center Diameter
h:mm:ss	hour:minute:second
IB	Inboard (pad swept area)
IBOD	Inboard Outer Diameter
ID	Inner Diameter
kPa	kilopascal
LH	Left Hand
LRO	Lateral Runout
Max	Maximum
mm/dd/yy	month/day/year
N/A	Not applicable
Nm	Newton meter
OB	Outboard (pad swept area)
OD	Outer Diameter
pos	Position
R	Radius
REV	Revolution
RH	Right Hand
rpm	revolutions per minute (min^{-1})
RTV	Rotor Thickness Variation
T	Time
TIP	Test Improvement Process
TV	Thickness Variation
V	Voltage

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW14926

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