



Inertia Dynamometer Accelerated Taper Wear Test for Disc Brakes

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 test procedure is used to accelerate disc brake lining taper wear development under controlled, repeatable conditions.

1.2 Applicability. This procedure is applicable to all disc brake systems.

1.3 Remarks. This test determines the disc brake lining taper wear that develops after being subjected to a series of taper wear generating "block" cycles. In addition, apparent friction and apparent piston travel are monitored during the wear blocks. Apparent friction, apparent piston travel, and torque hysteresis are evaluated before and after the test.

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW14933

GMW14974

GMW14986

GMW15142

3 Resources

3.1 Facilities. Milford Proving Grounds (MPG). Brake Component Development inertia brake 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.

3.1.2.1 Alternative test facilities and equipment must obtain an official GM Throughput Improvement Process (TIP) accreditation prior to submitting test data for vehicle programs.

3.2 Equipment.

3.2.1 An inertia brake dynamometer capable of performing torque control, pressure control, corrected pressure control, ramp, and modulated brake applies.

3.2.2 The following measurements shall be made and digitally recorded at 500 Hz:

3.2.2.1 Dynamometer speed (km/h).

3.2.2.2 Brake apply pressure (kPa).

3.2.2.3 Brake torque (N-m).

3.2.2.4 Inboard and outboard brake rotor temperature (°C).

3.2.2.5 Fluid displacement (mm³).

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3.3 Test Vehicle/Test Piece. Production representative brake corner hardware shall be used to produce the tailstock assembly.

3.4 Test Time.

Calendar time: 2 days
 Test hours: 36 hours to 48 hours
 Coordination hours: 4 hours

3.5 Test Required Information.

3.5.1 Contact test site for any required forms for testing.

3.6 Personnel/Skills. One (1) technician trained for the operation of an inertia brake dynamometer and to perform the duties described in section 4 is required.

4 Procedure

4.1 Preparation.

4.1.1 Embedded rotor thermocouple shall be installed per GMW14974.

4.1.2 The assembled corner Lateral Run Out (LRO) shall not exceed 50 micrometers (μm). The corner LRO shall be measured on the inboard face of the rotor, at a radius of 10 mm inside of the rotor Outer Diameter (OD) using a dial indicator, measured per GMW14933.

4.2 Conditions.

4.2.1 Environmental Conditions. Cooling air is provided to the brake. The cooling air temperature shall be between 10 °C and 30 °C. The cooling air humidity control is not required.

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 The dynamometer inertia shall be set as described in GMW15142 using Gross Vehicle Weight parameters.

4.3 Instructions. The test should be performed as described in Table 1.

Note: At the test requestor's discretion, the test may be performed without disassembly and taper wear measurements between blocks. If this is done, lining thickness is measured only before and after the complete test. This may be preferred in some cases where the disassembly and reassembly of the caliper is believed to carry risk of influencing the results; for example, in calipers that use a high temperature adhesive between the caliper and the pad backing plates, or insulators.

Table 1: Test Sequence and Instructions

Test Section Name	Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
Start-of-Test Brake Lining Measurements	Not Applicable (N/A)	N/A	N/A	N/A	Record the post-test brake lining thickness and mass. (GMW14986). Linings are drilled for measurement, but leave noise insulator (if applicable) intact.
Pretest Equipment Check					
Ramp applies	100	30	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature ≤ 90 °C

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Test Section Name	Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
Modulated applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two (2) modulations are achieved, reduce the maximum pressure to generate two (2) to three (3) modulations.	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Green					
Cold ramp applies	100	30	3	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 40^{\circ}\text{C}$
Warm ramp applies	100	30	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Modulated applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two (2) modulations achieved, reduce the maximum pressure to generate two (2) to three (3) modulations.	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Accelerated Burnish	95 to 65	50	50	Corrected pressure control stop, 3500 kPa/s apply rate to a 0.31G deceleration rate. Snubs completed on a 0.32 km (0.20 mi) cycle distance.	Initial brake rotor temperature $\leq 400^{\circ}\text{C}$
Cool Down	10	30	N/A	Allow the brake rotor to cool to $\leq 50^{\circ}\text{C}$.	
Burnished					
Cold ramp applies	100	30	3	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 40^{\circ}\text{C}$
Warm ramp applies	100	30	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Modulated applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two (2) modulations achieved, reduce the maximum pressure to generate two (2) to three (3) modulations.	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Apparent Piston Travel with Pre-conditioning					
Pre-conditioning	50	30	10	Torque control stops are made at 3500 kPa/s apply rate to 0.20G average deceleration.	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$

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Test Section Name	Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
Apparent piston travel	100	30	2	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Post Burnish Lining Wear Measurements: Remove pads from caliper and measure taper wear and mass per GMW14986. Reassemble and begin block 1.					
Taper Wear Block 1	100	25	200	Constant torque stops are made at 7500 kPa/s apply rate, 0.62G deceleration.	Initial brake rotor temperature $\leq 300^{\circ}\text{C}$ (all stops). No heating snubs are required.
Post Burnish Lining Wear Measurements: Remove pads from caliper and measure taper wear and mass per GMW14986. Reassemble and begin block 2.					
Taper Wear Block 2	100	25	200	Constant torque stops are made at 7500 kPa/s apply rate, 0.62G deceleration.	Initial brake rotor temperature $\leq 300^{\circ}\text{C}$ (all stops). No heating snubs are required.
Post Burnish Lining Wear Measurements: Remove pads from caliper and measure taper wear and mass per GMW14986. Reassemble and begin block 3.					
Taper Wear Block 3	100	25	200	Constant torque stops are made at 7500 kPa/s apply rate, 0.62G deceleration.	Initial brake rotor temperature $\leq 300^{\circ}\text{C}$ (all stops). No heating snubs are required.
Post Burnish Lining Wear Measurements: Remove pads from caliper and measure taper wear and mass per GMW14986. Reassemble and begin block 4.					
Taper Wear Block 4	100	25	200	Constant torque stops are made at 7500 kPa/s apply rate, 0.62G deceleration.	Initial brake rotor temperature $\leq 300^{\circ}\text{C}$ (all stops). No heating snubs are required.
End of Test Performance					
Ramp applies	100	30	5	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Modulated applies	100	30	3	0.5 Hz sinusoidal or ramp apply and release at 6200 kPa/s maximum. If $\leq$ two (2) modulations achieved, reduce the maximum pressure to generate two (2) to three (3) modulations.	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Apparent Piston Travel with Preconditioning					
Pre-conditioning	50	30	10	Torque control stops are made at 3500 kPa/s apply rate to 0.20G average deceleration.	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$
Apparent piston travel	100	30	2	Ramp applies are made at 5000 kPa/s apply rate to 13 000 kPa maximum pressure, or a 1.1G deceleration limit (whichever occurs first).	Initial brake rotor temperature $\leq 90^{\circ}\text{C}$

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Test Section Name	Braking Speed (km/h)	Cooling Air Speed (km/h)	Number of Stops/ Snubs	Control and Level	Condition
End of Test Brake Lining Measurements	N/A	N/A	N/A	N/A	Allow brake to cool to room temperature. Record the posttest brake lining thickness and mass. (GMW14986)

5 Data

5.1 Calculations.

5.1.1 Digital Signal Processing Rate. All test data is processed at 200 Hz.

5.1.2 Digital Signal Zeroing. Brake pressure and torque channels are digitally zeroed based on 0.5 s of digitally recorded data prior to each brake apply.

5.1.3 Hysteresis. For the second modulation during each modulated apply, determine the maximum difference in braking torque between the hydraulic release and apply conditions at a given pressure. Divide this difference by the peak torque and multiply by 100 to determine the percent torque hysteresis.

5.1.4 Apparent Friction:

Constant Deceleration Apply:

$$AF = \frac{\left(\frac{T}{2 * r_e} \right)}{P * A_p}$$

Ramp Apply:

$$AF = \frac{\left(\frac{T}{2 * r_e} \right)}{(P - P_{ho}) * A_p}$$

Where:

- AF** = Apparent Friction
- A_p** = Effective Piston Area (m²)
- P** = Hydraulic Pressure (kPa)
- P_{ho}** = Hold off Pressure (kPa)
- T** = Braking Torque (N-m)
- r_e** = Effective Radius, millimeter (mm) = Radius to the center of the piston pressure

5.2 Interpretation of Results.

5.2.1 Graphical Summaries.

5.2.1.1 Ramp Applies. Plot apparent friction (output) versus hydraulic apply pressure between 0 kPa and 12 000 kPa for each ramp apply. Plot green, burnished, and posttest applies in the cold and warm conditions on separate graphs (Figure A1). Also plot average apparent friction (output), Initial Brake Temperature (IBT), and maximum brake temperature versus stop number for each brake apply (Appendix A, Figure A2).

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5.2.1.2 Burnish Schedule. Plot average apparent friction (output), IBT, and maximum brake temperature for every fifth brake apply during the burnish schedule (Appendix A, Figure A2).

5.2.1.3 Apparent Piston Travel with Preconditioning. For Apparent Piston Travel (APT) calculations, use the compensated fluid displacement channel for these calculations. See glossary for definition/procedure. Graph the APT, millimeter (mm) versus hydraulic pressure, between 0 kPa and 12 000 kPa for each APT with Preconditioning ramp apply. Graph burnished warm and post fade warm APT ramp applies on separate graphs. (See example graph displayed in Appendix A, Figure A3,) Two (2) graphs total.

5.2.1.4 Hysteresis. Plot braking torque versus apply pressure for the second cycle of each modulated apply. Plot green, burnished and posttest applies on separate graphs (Appendix A, Figure A4).

5.2.1.5 Apparent Friction during Block Taper Wear Sections. Plot average apparent friction (output) for every tenth braking event in the block taper wear sections. (Appendix A, Figure A2).

5.2.1.6 Apparent Piston Travel During the Block Taper Wear Sections. Plot apparent piston travel at 500 kPa, 2500 kPa, 5000 kPa, and 7000 kPa versus stop number for every tenth stop. For any given braking event, if hydraulic pressure did not reach one of these thresholds, then the data point for that threshold is omitted from the plot (Appendix A, Figure A5).

5.2.1.7 Brake Torque Variation During the Block Taper Wear Sections. Plot the overall peak-to-peak Brake Torque Variation (BTV) (Nm), maximum peak-to-peak BTV (Nm) and the most significant BTV order versus stop number, for every tenth stop in the Block Taper Wear sections. (Appendix A, Figure A6).

5.2.1.8 Taper Wear During the Block Taper Wear Sections. Plot the peak radial and tangential taper wear in units of microns of lining wear thickness difference per millimeter of distance between measurement points. Plot this for each measurement recorded (Appendix A, Figure A7).

5.2.1.9 In-stop Temperature Rise and Residual Drag Torque During the Block Taper Wear Sections. Plot the rise in temperature in degrees Celsius for each brake plate and the residual drag torque (in the 0.5 s window prior to braking) versus stop number. (Appendix A, Figure A8).

5.2.2 Tabular Summaries.

5.2.2.1 Apparent Friction.

5.2.2.1.1 Ramp Applies. Create a table with the average apparent friction of the runs at 500 kPa, 1000 kPa, 5000 kPa, and 12 000 kPa for all stops, excluding the initial stop, at each brake condition (green, burnished, and posttest) for cold and warm. Include the numerical average of the pressure based average apparent friction values for each apply between 500 kPa and 12 000 kPa (or maximum attained pressure), the range and the variation between 500 kPa and 12 000 kPa at each brake condition. Also, determine within condition apparent friction range and variation (See example data in Appendix A, Table A1). If the ramp applies utilized the 1.1G cutoff prior to attaining the 12 000 kPa data point, the AF value for the highest pressure attained (rounded down to the nearest 1000 kPa value) should be reported with the corresponding pressure value.

5.2.2.2 Apparent Piston Travel with Pre-conditioning. For APT calculations, use the compensated fluid displacement channel for these calculations (see 7.1 for definition/procedure). Report average APT at 500 kPa, 1000 kPa, 5000 kPa, and 12 000 kPa using each of the first and second ramp applies of APT with preconditioning test in the burnished and post fade conditions (see Appendix A, Tables A2 and A3.) If the ramp applies utilized the 1.1G cutoff prior to attaining the 12 000 kPa data point, APT values for 12 000 kPa should be extrapolated from a regression analysis of the existing data. A notation should be made in the table that the value was extrapolated.

5.2.2.3 Hold off Pressure. Report average hold off pressure for all ramp applies, excluding the initial stop, at each ramp apply condition (green, burnished, and posttest. See Appendix A, Table A4.)

5.2.2.4 Hysteresis. For the second modulation, during each modulated apply, determine the maximum difference in braking torque between the hydraulic release and apply conditions at a given pressure. Divide this difference by the peak torque and multiply by 100 to determine the percent torque hysteresis. Report average maximum torque difference and average percent torque hysteresis for the green, burnished, and end of test conditions (Appendix A, Table A5).

5.2.2.5 Lining Measurement Summary. Report the start of test and end of test lining measurements.

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