

Disc and Drum Brake Dynamometer Low-Frequency Noise Test Procedure

RATIONALE

The development of this SAE Recommended Practice (RP) was based on a vehicle with known low-frequency noise from field and chassis dynamometer testing. The main test sequence reflected on this RP was able to reproduce on an inertia dynamometer the dominant frequencies measured on the vehicle. During the development of this RP, fixture design and fingerprinting for frequency response, along with the actual test sequence and the data analysis, proved to be the three main elements to allow the measurement and detection of noisy brake events below 1 kHz.

1. SCOPE

This test procedure outlines the necessary test equipment (test fixture, dynamometer, data acquisition system, etc.) and test sequence required to test for low-frequency brake noise (200 Hz to 1.25 kHz) on a brake noise dynamometer. It is intended to complement SAE J2521, which focuses on high-frequency brake squeal. This RP applies to passenger cars and light trucks with a gross vehicle weight rating below 4536 kg. Before using this RP for heavier vehicles, consult and agree with the test requestor and the testing facility.

1.1 Purpose

This recommended practice is intended to establish a common universally recognized method for performing a series of screening test sequences that identify the propensity of brake assembly to generate low frequency noise under a variety of test conditions

2. REFERENCES

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2521 Disc and Drum Brake Dynamometer Squeal Noise Test Procedure

SAE J2789 Inertia Calculation for Single-Ended Dynamometer Testing

3. DEFINITIONS

To facilitate the application of this SAE Recommended Practice, the following definitions apply.

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Documents

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3.1 APPARENT FRICTION FOR DISC BRAKES

Per Equation 1:

$$\mu = \frac{10^6 \cdot T}{2 \cdot (p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \quad (\text{Eq. 1})$$

where:

μ = apparent friction for disc brakes/unitless

3.2 DRUM BRAKE EFFECTIVENESS (C^*)

Per Equation 2:

$$C^* = \frac{10^6 \cdot T}{(p - p_{Threshold}) \cdot A_P \cdot r_{eff} \cdot \eta} \quad (\text{Eq. 2})$$

where:

C^* = effectiveness for drum brakes/unitless

T = output torque/N·m

p = brake pressure/kPa

$p_{Threshold}$ = minimum pressure required to start developing braking torque; unless otherwise indicated by the test requestor or measured as part of the project, use a zero value/kPa

A_P = total piston area acting on one side of the caliper for disc brakes; or total wheel cylinder area for drum brakes/mm²

r_{eff} = radial distance from centerline of the piston to the axis of rotation for disc brakes; internal drum diameter divided by 2 for drum brakes, unless other dimensions are provided by the requestor/mm

η = brake efficiency; unless otherwise indicated by the test requestor or measured as part of the project, use 1 (100%)

For dynamic brake applications, calculate the average-by-distance friction coefficient or effectiveness value between t_1 and t_2 per 8.1. For brake drag applications, calculate the average-by-time friction coefficient or effectiveness value between t_1 and t_3 per 8.2.

3.3 GROSS VEHICLE WEIGHT RATING (GVWR)

Maximum vehicle weight indicated by the manufacturer (kgf).

3.4 BRAKING SPEED

Linear speed at the onset of the brake application during stops or snubs where the speed reduces during the brake application (km/h).

3.5 DRAG SPEED

Linear speed at the onset of the brake application during drag events where the speed remains constant during the brake application (km/h).

3.6 INITIAL BRAKE TEMPERATURE (IBT)

Rotor or drum temperature at the start of the brake application (°C).

3.7 PRESSURE OR SPEED PROFILE

Brake application where the speed (or the brake pressure) is held constant and the pressure (or the brake speed) changes in discrete steps to induce potential low-frequency noisy events. See Section 8.

3.8 TIRE DYNAMIC ROLLING RADIUS

Equivalent tire radius that will generate the revolutions per mile (RPM) published by the tire manufacturer for the specific tire size per Equation 3. Use the tire dynamic rolling radius to calculate the dynamometer rotational speed for a given linear vehicle speed (mm).

$$RR = \frac{1\,609\,344}{2 \cdot \pi \cdot RPM} \quad (\text{Eq. 3})$$

where:

RR = tire dynamic rolling radius/mm

RPM = tire manufacturer specification for revolutions per mile and typically shown for the tire size on the manufacturer's website

4. TEST EQUIPMENT

- 4.1 Single-ended brake inertia-dynamometer capable of performing dynamic brake applications with deceleration- or pressure-controlled brake applications. Also, capable of conducting brake drag at constant pressure, and brake drags with brake pressure profiles.
- 4.2 Semi-anechoic chamber of sufficient size (and features) to accommodate the test fixture, the passive roller assembly, and the noise measurement system (microphone and accelerometers).
- 4.3 Passive roller to impose radial load on the brake corner through the tire.
- 4.4 Reversible motor and drive control capable of (a) conducting the brake drag applications at no less than 90% of the nominal drag speed, (b) conducting speed profiles where the brake speed follows a specific sequence versus time independent of the brake torque or pressure, and (c) providing the torque required when using inertia simulation (electric inertia) during brake stops or snubs.
- 4.5 Water Spray System
 - 4.5.1 During water spray test sections for a disc brake, water is sprayed onto the rotor outer diameter near the caliper's bracket. For drum brakes, water is sprayed at the drum to backing plate interface from slightly above and from the inboard side.
 - 4.5.2 A flow rate of 6 L/min $\pm$ 2 L/min from a distance of 25 cm $\pm$ 5 cm.
 - 4.5.3 The water stream shall have a fan shape and allow soaking of the inboard and outboard linings and rotor cheeks.

- 4.6 Control system capable of performing brake applications at constant pressure, pressure profiles, constant deceleration (torque control), and speed profiles.
- 4.6.1 Pressure ramp rate of at least 10000 kPa/s $\pm$ 2500 kPa/s and a maximum pressure of at least 16000 kPa.
- 4.6.2 Overshoot of less than 100 kPa during dynamic brake applications.
- 4.6.3 Average pressure control within 250 kPa of target value (set-point) during pressure profiles.
- 4.6.4 Deceleration control and overshoot within 0.5 m/s² of target value (set-point).
- 4.7 Cooling air system directed at the brake.
- 4.7.1 Control the air speed such that it will not be so high as to blow away wear debris or create noise above the background limit indicated on item 7.3.3. The cooling air may remain on during the brake events if the background noise level is satisfactory. If needed to meet the noise threshold, turn the cooling air off during the brake event. Alternatively, divert the cooling air away from the brake during the brake applications.

NOTE 1: Depending upon the project, other threshold levels could be more appropriate, like brake noise evaluation for electric vehicles. In such cases, confirm with the test requestor and the testing facility.

- 4.7.2 Set up the duct outlet 300 to 400 mm away from the rotor outside diameter with air duct with a hydraulic diameter 200 to 300 mm. Adjust cooling air to 10 m/s (35 km/h) measured at the duct outlet; if needed, adjust to meet the background noise level from 7.3.3.

NOTE 1: In cases where the above conditions cannot be achieved, define with the test requestor and document it on the final test report

NOTE 2: Alternatively, adjust cooling air flow between 1000 m³/h and 2000 m³/h while ensuring background noise level per 7.3.3.

NOTE 3: Since the cooling air setup is a critical subsystem of the inertia dynamometer which effects test variability and test duration, ensure proper definitions and test conditions are defined for the test project. Measure airflow, assess cooling rates at specific temperatures and test speeds, review cycle times, and observe overall temperature regimes during the tests to better understand the conditions and effects on noise and friction behavior.

- 4.7.3 Environmental control system capable of controlling temperature from -10 °C and above. Except for the water spray sections, control brake cooling air temperature and relative humidity to settings indicated in Section 9. Use a psychrometric chart to find acceptable air temperature and relative humidity combinations. During cold modules below the dew point of the environmental control system, control only the cooling air temperature.
- 4.7.4 See Figure 1 for two typical setups of cooling air for disc brake assemblies. Document on the test report the actual cooling air orientation relative to the brake and the brake rotation.

NOTE 1: In order to ensure efficient and stable cycle times during the test, it is recommended during cold sections to set the cooling air temperature to approximately 10 °C below the IBT.

NOTE 2: In order to keep similar and consistent cooling behavior of the brake assembly (including noise insulators or shims) for the same project, in addition to keeping the cooling air setup the same, use the same fixture and brake orientation (left- or right-hand) in agreement with the test requestor and the testing facility.