



SURFACE VEHICLE INFORMATION REPORT

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Taxonomy and Guidelines for Design, Fabrication, and Installation of Brake NVH Fixtures for Inertia Dynamometer Testing

RATIONALE

Brake testing and measurements for noise, vibration, and harshness using inertia dynamometers are some of the most prevalent types of laboratory methods across the automotive industry.

Decades of inertia dynamometer testing in multiple regions have led to multiple fixture design philosophies and methodologies, with substantial effects on the test results. Also, in the current landscape of the automotive manufacturing industry, vehicles are designed in one location, manufactured at another location(s), and sold all over the world with significant differences in environmental conditions during their life-cycles. Efforts to reproduce vehicle-level conditions in the laboratory setting (using a single brake corner assembly) need to aim at reducing redundancy, conflicting results, or high-variability in test outcomes during a given test program.

This SAE Information Report (IR) provides the industry with a systematic overview of the main types of fixture designs as a function of (a) the level of hardware involved, (b) the preloading method, and (c) type of frame utilized to adapt the vehicle/brake assembly to the dynamometer. This IR also includes guidelines for best practices regarding fixture fabrication, verification, and installation in the inertia dynamometer test chamber.

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Documents

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1. SCOPE

This IR defines a general taxonomy (classification) of the most common fixture designs. This IR provides guidelines for design, fabrication, and installation to improve the way tests repeat, reproduce, and correlate to vehicle conditions. The different types of fixtures in this IR (including their preloading) apply to single-ended brake inertia dynamometer NVH testing, with a frequency range between 1.25 kHz and 16 kHz (per SAE J2521). This IR applies to passenger car and light trucks with a gross vehicle weight rating of 4536 kg or below. This IR does not address other sources of variability such as (a) test procedure itself, (b) environmental conditions, (c) dynamometer design, including its NVH test chamber, (d) data collection and data analysis methods, and (e) part-to-part, batch-to-batch, and design-level variation for brake and suspension hardware.

1.1 Purpose

This IR presents general engineering best practices (with some examples) related to inertia dynamometer fixtures to measure and characterize brake squeal. It also describes and illustrates, with examples, the different preloading systems used to impose/replicate road load during laboratory testing.

2. REFERENCES

2.1 Applicable Documents

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.

2.1.1 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

3. GENERAL CONSIDERATIONS

The same fixture style can respond and behave with significant differences when used with various types of loading systems on several brake assemblies and dissimilar test systems (inertia dynamometer). It is crucial to have the proper and early understanding of the different fixture design options, the fabrication/embodiment techniques or preferences, and the loading system. This understanding (and its related decisions) for a particular testing campaign, along with the vehicle hardware, determine the fidelity and relevance of the test and measurement results. The brake NVH fixture works as part of a more extensive system and has a significant influence on the results of the test.

The acting test requestor, in close coordination with the testing facility, and the application engineer (or end-user of the test results), need to coordinate and document the testing process. The coordination involves among other aspects: vehicle application, hardware and components under testing, level of replication of vehicle hardware, loading, test cycles and maneuvers, logistics, requirements for reproducibility in different test systems or test facilities, capabilities and resources available for fixture design, fabrication, and installation, and overall timing and budget constraints for the project.

Figure 1 illustrates the core technology systems and subsystems involved in NVH testing in a block diagram.

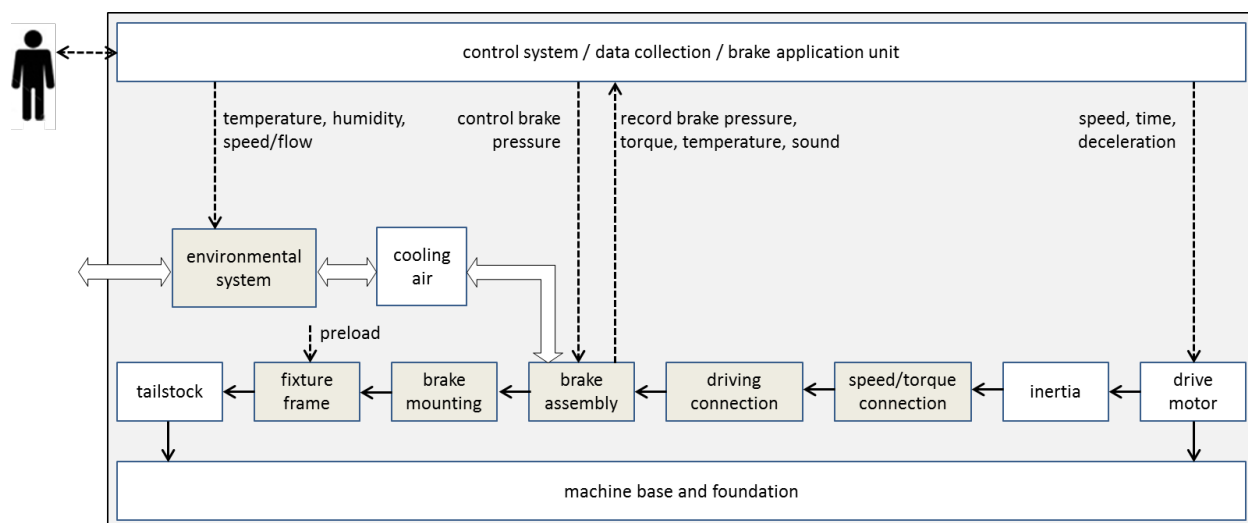


Figure 1 - Block diagram for inertia-dynamometer NVH system
Mass represented in thick white arrows; energy in solid lines; signals and data in dashed lines

4. GENERAL GUIDELINES FOR FIXTURE DESIGN

These are some guidelines to consider during the design phase of the fixture for a given project. Take these guidelines as best practices, especially for new projects where there are no legacy designs or test results, which may make changes to the fixture design more challenging. In case the project is a continuation of previous test campaigns, discuss with the project team which elements are worth considering, without compromising the overall scope, timeline, and budget of the program. For new projects or new testing and measurement campaigns, review these guidelines and incorporate as much as feasible considering technical and logistical constraints.

4.1 Fixture Levels

In addition to the inertia dynamometer itself and articles under testing, the brake fixture is the most critical subsystem for the test. The main factors to consider at the time of defining which level of the fixture to design and plan for can include:

- a. Amount of vehicle hardware available.
- b. NVH frequency range of interest.
- c. Scope and goals of the test campaign.
- d. Legacy fixture style established as the general engineering practice.
- e. Ability to accommodate the intended fixture design onto the test dynamometer and its mating interfaces.

Within NVH testing, there are three typical levels of fixtures for squeal testing. See Table 1. Values in parentheses indicate components identified in Figures 2 to 10.

Table 1 - Fixture levels for squeal noise testing

Item No.	Vehicle Component	Fixture Level		
		L1 (Knuckle)	L2 (Suspension)	L3 (Full-Axle)
1	Brake disc or drum	yes	yes	yes
n.s.	Friction material	yes	yes	yes
2	Brake caliper/drum brake assembly	yes	yes	yes
n.s.	OE brake hose	yes	yes	yes
3	Wheel hub and bearing	yes	yes	yes
n.s.	Driveshaft (if needed) or equivalent	yes	yes	yes
4	Suspension knuckle	Yes	Yes	Yes
5	Dust shield or equivalent shims	Optional	Yes	Yes
n.s.	Fasteners and bolts	Yes	Yes	Yes
n.s.	Wheel center, rim, or equivalent	Optional	Optional	Optional
6	Fixture accelerometer	Yes	Optional	Optional
7	Caliper accelerometer	Yes	Optional	Optional
8	Stabilizer arm linkage ¹	—	Yes	Yes
9	Spring, strut, or and shock absorber with bushings	—	Yes	Yes
10	Tie rod and steering arm when applicable	Optional	Yes	Yes
11	Control arms (only lower shown)	—	Yes	Yes
12	Control arm bushings	—	Yes	Yes
13	Stabilizer arm bush/bracket ¹	—	Yes	Yes
14	Stabilizer bar (swaybar) ¹	—	Yes	Yes
15	Subframe with bushings	—	Optional	Yes
16	Wheel and tire	Optional	Optional	Optional
n.s.	Track bar for rigid axles	—	—	Yes

¹ This component is mandatory when using it for preloading the fixture for testing, or when the stabilizer arm connects to the knuckle.

n.s. Element not shown in Figures 2 to 10.

4.1.1 Level 0 Fixture (Post or Universal)

This type of fixture, which is adequate for performance, wear, or brake emissions testing, is deprecated (unacceptable) for NVH measurements. Since this level of fixture does not include any mounting or attachment components from the vehicle, the frequency response renders the test measurements (squeal noise and associated vibrations) as inadequate. Even though some fixtures may coincide with the natural frequencies from the vehicle, the actual response during dynamic braking and excitation would not be appropriate or relevant. This fixture comprises the brake caliper, brake disc or drum assembly, brake pads, and (caliper or brake pad) hardware. The actual mounting onto the tailstock (or angle plate) requires fabricated steel blocks with a representative wheel hub to mount the brake rotor. This style of fixture requires detailed measurements of the relative mounting positions of the different components, including running clearances in the axial and radial directions. See Figure 2 for a diagram of this level of the fixture.

NOTE: Since this level of fixture is not recommended for squeal noise tests, Level 0 fixture is not included further on this IR.

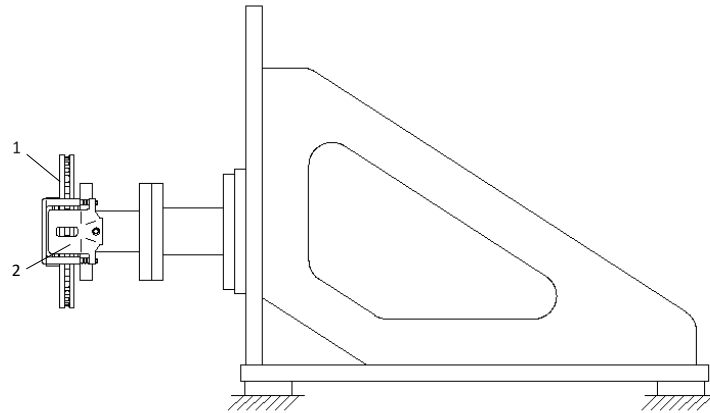


Figure 2 - Level 0 fixture
 1: Brake disc or drum; 2: Brake caliper/drum brake assembly

4.1.2 Level 1 Fixture (Knuckle)

This type of fixture is common for squeal measurements. At a minimum, constrain the control arm, steering arm, and strut mount points to the fixture base. For all squeal tests, mount one accelerometer to the caliper and one accelerometer to the fixture base. The acceleration levels on the caliper and fixture can be compared during a squeal event to determine whether the noise is brake squeal or fixture induced squeal.

As a guideline, for a noisy brake event, the level of the acceleration measured on the caliper at the squeal frequency needs to be twice the acceleration measured on the fixture. Before commencing a specific testing campaign, verify with the test requestor if this level of fixture is adequate for the project. This style is the minimum level for disc and drum brake assemblies. See Figure 3 for a diagram of this level of fixture.

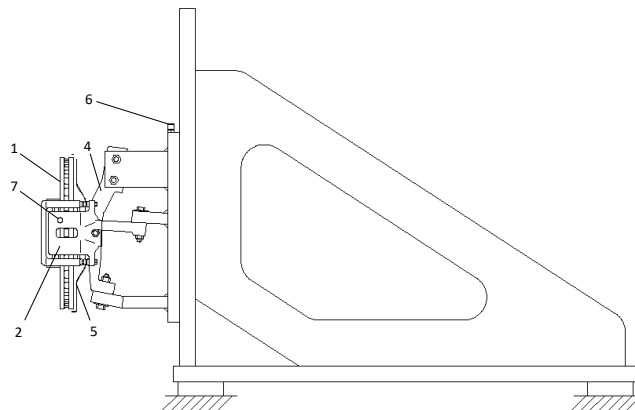


Figure 3 - Level 1 fixture for disc brakes
 1: Brake disc or drum; 3: Wheel hub and bearing; 4: Suspension knuckle;
 5: Dust shield or equivalent shims; 6: Fixture accelerometer; 7: Caliper accelerometer

Some of the main benefits and limitations of this level of fixture are:

Table 2

Benefits	Limitations
a. Ease of fabrication b. Limited level of hardware required c. Ease of handling (setup and storage)	a. Inadequate frequency response b. 1.5 kHz threshold for low-frequency squeal noise

4.1.3 Level 2 Fixture (Suspension)

This type of fixture includes at least the hardware connecting the brake assembly to the vehicle subframe.

This approach provides the minimum configuration for mass damping and transmissibility of vibrations (related to squeal) through the corner assembly. This level of fixture renders itself to include supplementary systems to impose external loads, which enhance the ability to recreate vehicle-level noises on the dynamometer. As a general recommendation, include as much vehicle hardware as feasible to represent the intended vehicle configuration (prototype or production level). Whenever possible, include vehicle suspension with vehicle hardware, fasteners, and bushings. See Figure 4 for a diagram of this level of fixture. The actual setup for the test also depends on the combination of the fixture level per this item and the loading system per item 5.

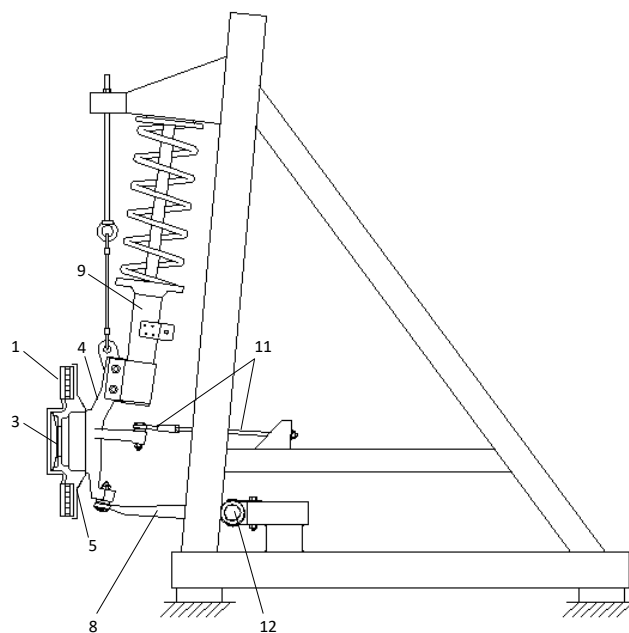


Figure 4 - Level 2 fixture

- 1: Brake disc or drum; 3: Wheel hub and bearing; 4: Suspension knuckle;
5: Dust shield or equivalent shims; 8: Stabilizer arm linkage;
9: Spring, strut, and/or shock absorber with bushings;
11: Control arms (only lower shown); 12: Control arm bushings