



SURFACE VEHICLE STANDARD

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Laboratory Measurement of the Composite Vibration Damping Properties of Materials on a Supporting Steel Bar

RATIONALE

This standard discusses a test methodology to measure the damping performance of a material bonded to a bar over a range of frequencies and temperatures found applicable to many transportation systems. Measurements typically include the composite loss factor (damping material bonded to a steel bar) at frequencies between 100 Hz and 1000 Hz and at temperatures between -20 °C and 55 °C. The user has the option to use one of three different size steel bars based on the materials in the intended application.

1. SCOPE

This SAE Standard describes a laboratory test procedure for measuring the vibration damping performance of a system consisting of a damping material bonded to a vibrating cantilevered steel bar. The bar is often called the Oberst bar (named after Dr. H. Oberst) and the test method is often called the Oberst bar test method. Materials for damping treatments may include homogeneous materials, nonhomogeneous materials, or a combination of homogeneous, nonhomogeneous, and/or inelastic (such as aluminum foil) materials. These materials are commonly installed in transportation systems such as ground vehicles, marine products, and aircraft to reduce vibration at resonance, and thus reduce the noise radiation from the vibrating surface. The test method described herein was developed to rank order materials for application on panels using general automotive steel but also may be applicable to other situations or conditions.

Damping performance for most materials and systems varies as a function of both frequency and temperature. Accordingly, this test procedure includes provisions for measuring damping over a range of frequencies and temperatures found applicable to many transportation systems. The measured damping performance will be expressed in terms of composite loss factor, η_c , within the frequency range of approximately 100 to 1000 Hz, and over the useful temperature range for the given application. The term composite refers to the steel and damping material combination. The composite loss factor is, therefore, dependent upon the thickness, damping, and modulus of both the steel and damping material layer.

The test procedure described here is based on the method described in ASTM E756. However, this SAE document differs from the ASTM E756 method in that the SAE practice specifies the bar material, three bar sizes, the mounting conditions of the test samples, and suggested standard interpolation frequencies. This document provides a means of rank ordering damping materials according to their composite loss factor values from test samples that represent typical sheet metal applications.

The material properties of the damping material alone, including Young's modulus E , and the material loss factor η , may be computed from the test samples specified in this document if additional conditions are met. ASTM E756 defines these additional conditions as well as the equations to be used to compute the damping material properties for the single layer (Oberst beam) configuration.

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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 TSB003 Rules for SAE Use of SI (Metric) Units

Saha, P. and Chahine, J., "The Thought and Reasoning Behind Developing SAE J1637 - Vibration Damping Test Method," SAE Technical Paper 931320, 1993, <https://doi.org/10.4271/931320>.

Moritz, C. and Deshpande, S., "SAE J1637 Vibration Damping Round Robin Study," SAE Technical Paper 2017-01-1881, 2017, doi:10.4271/2017-01-1881.

2.1.2 ANSI Accredited Publications

Copies of these documents are available online at <http://webstore.ansi.org/>.

ANSI S1.1 Acoustical Terminology

ANSI S2.9 Nomenclature for Specifying Damping Properties of Materials

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E691 Conducting an Interlaboratory Study to Determine the Precision of a Test Method

ASTM E756 Measuring Vibration - Damping Properties of Materials

2.1.4 DIN Publications

Available from Deutsches Institut für Normung e.V., Burggrafenstrasse 6, 10787 Berlin, Germany, www.din.de.

ISO 6721-1 Plastics - Determination of Dynamic Mechanical Properties - Part 1: General Principles

ISO 6721-3 Plastics: Determination of Dynamic Mechanical Properties - Part 3: Flexural Vibration

2.1.5 JASO Publications

Available from Society of Automotive Engineers of Japan, 10-2, Gobancho, Chiyoda-ku, Tokyo 102-0076, Japan, Tel: +81-3-3262-8211, www.jsae.or.jp.

JASO M329 Asphalt Sheet for Automobiles

3. TEST METHOD

The method is based on exciting the damped bar at various modes of vibration at a given temperature of interest, and obtaining the damping performance using the half-power bandwidth technique. In this technique, first the resonant frequency, f , at a given mode of the bar is measured. Next, the lower and upper frequencies (f_l and f_u , respectively) are measured on the response curve on either side of the resonant frequency where the levels are 3 dB lower than the level at resonance (3 dB down points or half-power points). The difference of f_u and f_l , in this case, is called the half-power bandwidth. This procedure is repeated for other modes of vibration and temperatures. The composite damping performance is given by Equation 1 (see Figure 1):

$$\eta_c = \frac{\Delta f}{f}$$

where:

$$\Delta f = f_u - f_l$$

Δf = frequency bandwidth, Hz

f = resonant frequency, Hz

η_c = composite loss factor at resonant frequency, f , dimensionless

4. INSTRUMENTATION

The instrumentation to be used is as follows (see Figure 2 for a schematic of a typical setup):

- 4.1 A bar mounting fixture (test fixture) that is heavy, rigid, and can provide adequate force at the clamped end of the bar to simulate the cantilever boundary conditions (clamped-free).

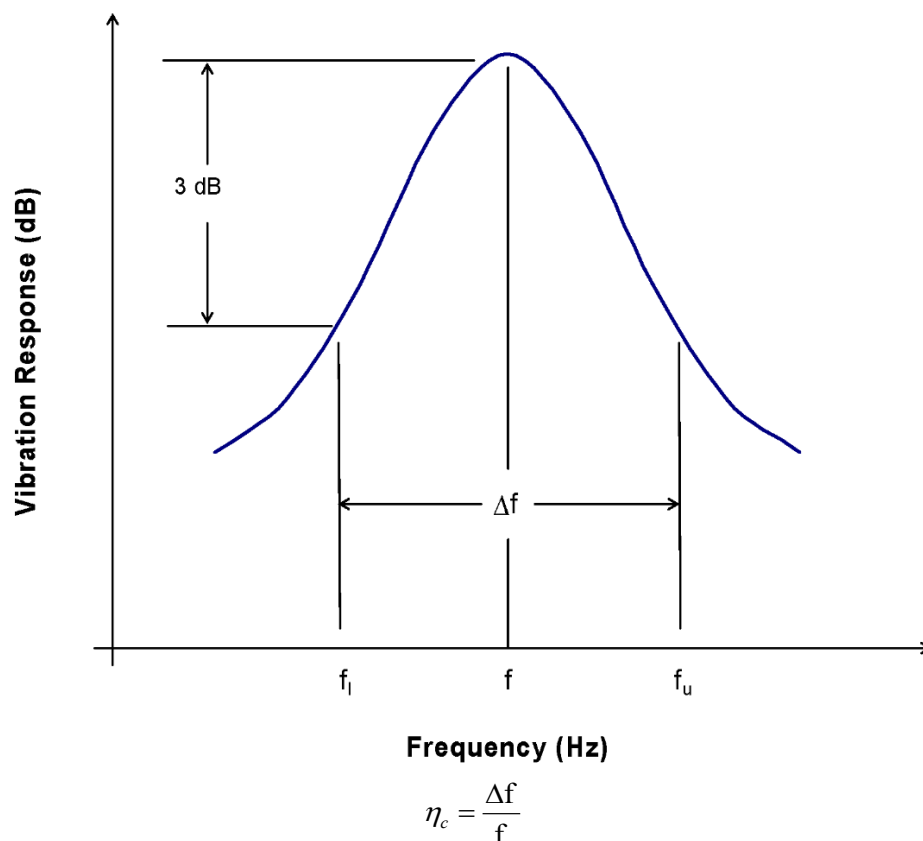
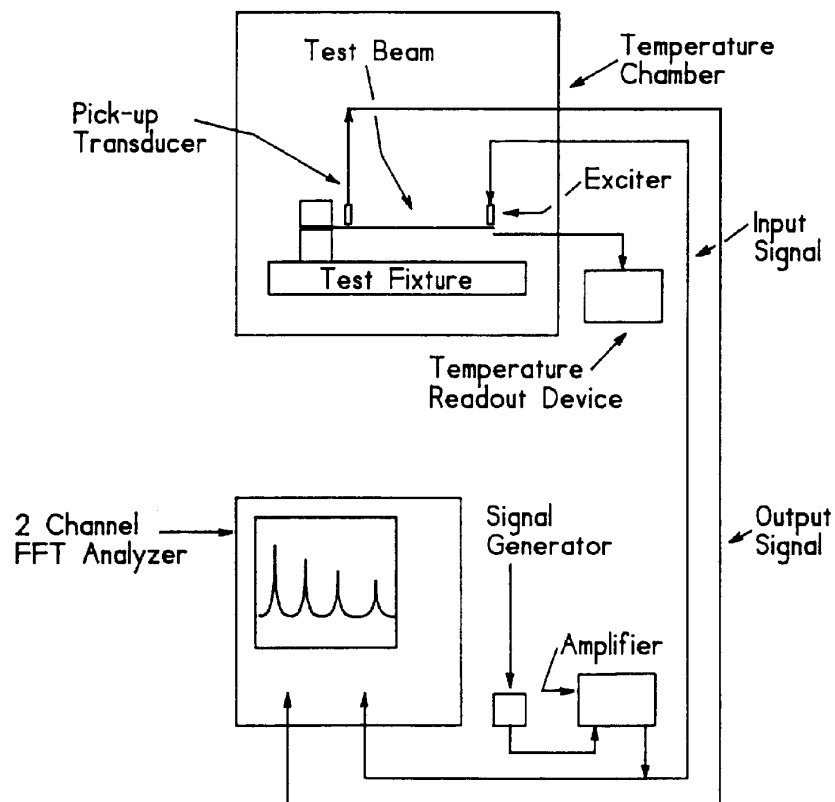


Figure 1 - Composite damping performance computation



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NOTE: Horizontal bar orientation is shown. A vertical bar orientation is also commonly employed. Also, the locations of the transducers may be reversed.

Figure 2 - Schematic of a typical test setup for damping performance evaluation

- 4.2 A temperature chamber so that the sample can be maintained at the appropriate temperature.
- 4.3 Two transducers with associated power supplies and signal conditioners—one applies the excitation force (called the excitation transducer or the exciter) and the other measures the response of the bar (called the pick-up transducer). The purpose is to measure only the damping of the test sample, without any additional damping from any other effects. Therefore, the pick-up transducer used is often a non-contacting type transducer. If a contacting type transducer is used as a pick-up transducer, extreme care should be taken to ensure that the transducer does not contribute to the damping of the test sample (i.e., overdamp the test sample). The mass of the contacting type transducer shall not exceed 0.5 g. See 7.2.2. The excitation transducer is generally a non-contacting type electromagnetic vibration exciter.
- 4.4 A signal generator that generates a sinusoidal or a random signal. The signal is applied to the excitation transducer by means of a power amplifier. The response of the bar will be measured using the pick-up transducer.
- 4.5 An analyzer or an analysis system capable of determining the transfer function between the excitation signal and the response signal. Examples include: a two-channel spectrum analyzer (e.g., based on Fast Fourier Transform algorithm) that is suitable for the signal, such as the random noise signal. Alternatively, a single channel system with separate excitation and response analysis systems can be used. However, efforts must be made to make the excitation force constant with frequency so that the response can be measured directly. The minimum amplitude precision of the measuring system should be 0.1 dB. The minimum frequency resolution of the measuring system should be 0.1 Hz.

5. TEST SAMPLE

5.1 Test Bar

The test bar to be used is as follows:

- 5.1.1 The metal for the bare bar should be steel. Precision ground gage stock (or also called precision ground flat stock) bars should be used as the Oberst bar for damping tests. Precision ground gage stock bars are commercially available (see Appendix A). Alternatively, the bare bar may be manufactured by machining a mild steel bar stock. A new bar should be used for each application. Selection of which of the three bar sizes to use should be based on the steel thickness of the intended application. Multiple Oberst beam sizes may be tested to determine the composite loss factor variation with steel thickness. For the purpose of rank ordering damping materials in extensional layer constructions, any one of the three bar sizes is sufficient.

Overdamping can occur when an excessively high damping material thickness is used on the bar. Overdamping can cause the response of the bar vibration to be reduced to a level, which cannot be used to measure the composite loss factor. The damping material thickness at which overdamping occurs is based on the given material's damping properties. If overdamping occurs, the transfer function of the bar will be very flat and the modes will be nearly eliminated. To prevent this from occurring, a thicker bar size may be used.

- 5.1.2 The dimensions of the bars shall be as shown in Table 1 (also see Figure 3).

The modes of vibration for each beam size (uncoated) can be computed theoretically. Calculated values for modes two through five for the three SAE J1637 bar types are provided in Table 2. Experience has been that measured values of mode-frequencies within 2% of the calculated values at 25 °C produce repeatable test results. Figure 4 shows the typical frequency response of a bare Oberst bar.

Table 1 - Test bar dimensions

Bar	Free Length, L_T (mm)	Minimum Clamping Length (mm) ⁽¹⁾	Minimum Total Length, L (mm)	Minimum Width, W (mm) ⁽²⁾	Thickness, H_2 (mm)
A	200	25	225	12.7	0.8
B	216	25	241	12.7	1.0
C	254	25	279	12.7	1.6

⁽¹⁾ The free length of the bar is a critical factor in determining the frequencies of the modes of vibration. The clamping length of the bar is important for ensuring that the prerequisite cantilever boundary condition is present for the test. The total length is the sum of the free length and the clamping length. The clamping length value given in the table is the minimum that can be used. It has been found that longer clamping lengths of the bar (with corresponding longer clamps on the fixture) tend to better match the desired cantilever condition. It is recommended that a clamping length longer than the minimum be used if possible. A clamping length of 50 mm has been found to perform especially well.

⁽²⁾ Since the width of the bar is not a critical factor in determining the frequencies of the modes of vibration, the width given in the table was chosen as a minimum practical width for preparing a sample bar and obtaining good clamping conditions. Wider bars may be used if they are more convenient to obtain. However, because the bar is intended to be excited in its bending modes only, there is a limit on the width of the bar. If the bar is too wide for a given thickness, torsional modes may be excited that will complicate the damping measurement. To avoid these torsional modes, the bar width should not exceed 50 mm.

Dimension tolerances:

- a. Mounted free length: ± 0.5 mm
- b. Total length: ± 1.0 mm
- c. Thickness: ± 0.03 mm