2022-038.3R
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Dipl.-Ing. Denis Blanchet
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Subject: **Results of Oberst Bar Vibration Damping Test of One Bar**
dBVibroAcoustics s.r.o. Purchase Order No. 20220321-1A
Kolano and Saha Engineers, Inc. Project No. 2022-038.3

Dear Mr. Blanchet:

At your request, Kolano and Saha Engineers, Inc. (K&SE) conducted an Oberst bar damping test to evaluate the damping performance of one constrained layer beam that you provided. The scope of the study was to determine the material properties of the viscoelastic material (VEM) that include the material loss factor and the shear modulus of the VEM. The loss factor is the modal loss factor.

This report includes the following:

- Letter
- Figure 1
- Tables 1 and 2
- Exhibit 1A

Test Sample

One viscoelastic material (VEM) was sandwiched between two 1 mm thick steel bars to form a constrained layer configuration. In this report a sandwiched beam is identified as a constrained layer construction. The VEM that was tested is:

		Manufacturer Data	
Sample No.	**Sample Description**	**Thickness (mm)**	**Density (kg/m^3)**
S1	High Temp Damping #1 (6+26)	0.0699	1070

Measured thickness and surface density information is provided for the VEM only i.e., without steel bars and for "**information purposes only**".

Test Method and Measurements

Measurements were made in accordance with SAE Standard J1637 Feb22, "*Laboratory Measurement of the Composite Vibration Damping Properties of Materials on a Supporting Steel Bar",* as much as possible. However, the bar size and the test temperatures were different from what is mentioned in the standard. Kolano and Saha Engineers, Inc. is accredited by ANSI National Accreditation Board (ANAB) to perform this test per ISO/IEC 17025.

The nominal dimensions of the steel bars were: total length 290 mm, mounted free length 254 mm, thickness 1 mm, and width 20 mm. The VEM was bonded in between two steel bars (from just after the clamping area to the free end). The gap between the two steel bars in the clamping area was filled by filler materials such as steel shim stock. This prevented putting any clamping force on the VEM so the measurements can be done properly. The test bar was prepared by the VEM manufacturer Trelleborg Sealing Solutions Kalmar AB. dBVibroAcoustics sent the bar to K&SE for measurements. Figure 1 shows a schematic of a typical test bar. The test bar was tested at three different temperatures. These were 20°C, 50°C, and 100°C.

Tests were made on a K&STLE DAMP® fixture to measure various modes of vibration that were generally between 100 Hz and 1000 Hz for each test bar using a random signal. The resonant frequency and the half power bandwidth frequency (frequency difference between 3 dB downpoints from the resonant peak where possible) of each mode needed for composite loss factor (η_c) computation was read directly from the K&STLE DAMP® automated system developed through MATLAB. A complete description and calibration records of the instrumentation used are on file with K&SE. In testing between two consecutive temperatures (i.e., between 20ºC and 50ºC; and between 50ºC and 100ºC), the bar was kept in the temperature chamber for 90 minutes. It took approximately 60 minutes to transition from one temperature to another, allowing for approximately 30 minutes to be conditioned (soaked) at that temperature before measurements.

The precision of measurement by this method, based on 95% confidence limit, is greater than sample to sample variation. The repeatability of tests made of identical samples at K&SE is expected to be within the coefficient of variation of 20%, as mentioned in the SAE Standard.

Results

The measured composite loss factor results of the VEM, under constrained layer configuration, are presented in tabular form in Table 1. The computed material loss factor and material shear modulus values have also been presented in this table. Computation of material properties were based on Equations 8 and 9 of ASTM standard E756-05 (Reapproved 2017), where the bare bar information was obtained from theory using Equation 2 of the ASTM standard and using 7850 kg/m^3 as the density of steel. The equations for computing the material properties are also provided in Table 2.

Table 1 also provide the interpolated values for composite loss factor, material loss factor and material shear modulus. These values are computed at 200 Hz, 400 Hz, 600 Hz, and 800 Hz for each temperature. These values are based on linear interpolation of two sets of data points where the frequency and the loss factor/modulus information are provided in a logarithmic scale, per Equation 3 in the SAE J1637. The composite loss factor values at different temperatures are also presented graphically in Exhibit 1A.

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Mr. Blanchet, we appreciate this opportunity to be of service to dBVibroAcoustics s.r.o. Please contact us should you have any questions. We look forward to working together again.

Sincerely,

KOLANO AND SAHA ENGINEERS, INC.

Codi Anderson
Associate Project Engineer

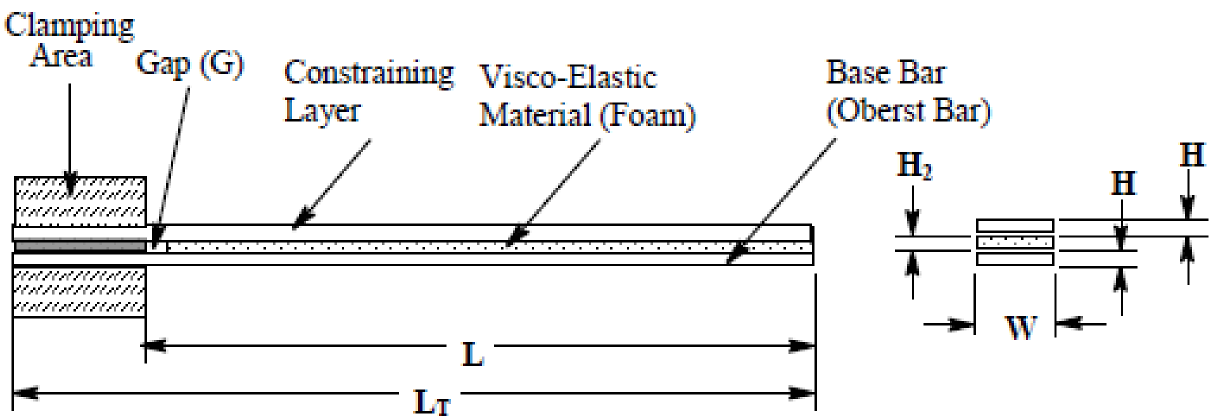
Reviewed by

Pranab Saha, Ph.D., P.E., Fellow ESD & SAE
INCE Board Certified
SAE Master Instructor
Principal Consultant

FIGURE 1

A TYPICAL TEST SAMPLE FOR OBERST BAR DAMPING TEST

Typical Oberst Bar with Roots



LEGEND

L	=	Free Length of the Oberst Bar: 254 mm This is also the Length of the Damping Material
L_T	=	Total Length of the Oberst Bar: 290 mm
W	=	Width of the Oberst Bar: 20 mm
H_2	=	Thickness of the Damping Material: 0.0699 mm
H	=	Thickness of the Constraining Layer: 1 mm

NOTE

The damping material should not touch the clamping mechanism or the test fixture. The gap (G) between the clamping device and the material should be less than or equal to 0.5 mm.

The damping material was a constrained layer damper.

Table 1

DAMPING RESULTS FROM OBERST BAR TESTS USING K&STLE DAMP

Tests Conducted for: **dBVibroAcoustics s.r.o.**
Sample Manufacturer: **Trelleborg Sealing Solutions Kalmar AB**
Sample Description: S1: High Temp Damping #1 (6+26) **Cure Cond:**

Sample Type: Constrained **Classification:**

		Manf. Data VEM	Meas. Data Test Bar	Steel Bar	Units
Sample Information	Thickness:	0.0699	0.1	1	mm
	Surf. Dens:	0.07	0.07	7.85	kg/m^2
	Density:	1070	1070	7850	kg/m^3
	Free Length:	254	254	254	mm

TEST TEMPERATURE	MODE	Measured Data: RESONANT FREQUENCY f_c (Hz)	Measured Data: COMPOSITE LOSS FACTOR η_c	Computed Data: MATERIAL LOSS FACTOR η_1	Computed Data: MATERIAL SHEAR MODULUS G (Pa)
20 °C (68 °F)	2	154	0.055	0.110	1.13E+07
	3	410	0.077	0.151	2.56E+07
	4	759	0.098	0.193	4.04E+07
	5	1990	0.147	0.815	4.97E+08
	Interpolated	200	0.060	0.120	1.40E+07
		400	0.076	0.150	2.51E+07
		600	0.089	0.176	3.39E+07
		800	0.100	0.209	4.62E+07
50 °C (122 °F)	2	136	0.207	0.415	6.76E+06
	3	348	0.217	0.452	1.31E+07
	4	633	0.251	0.564	1.87E+07
	5	963*1	0.287	0.745	2.09E+07
	6	1437*2.5	0.249	0.641	3.14E+07
	Interpolated	200	0.211	0.430	8.87E+06
		400	0.224	0.476	1.43E+07
		600	0.247	0.553	1.82E+07
		800	0.270	0.659	1.99E+07
100 °C (212 °F)	2	90	0.236	1.167	7.59E+05
	3	238	0.189	1.495	1.17E+06
	4	458	0.152	1.597	1.64E+06
	5	748	0.126	1.697	2.06E+06
	6	1119	0.105	1.360	3.21E+06
	Interpolated	200	0.197	1.430	1.08E+06
		400	0.159	1.575	1.53E+06
		600	0.137	1.651	1.86E+06
		800	0.123	1.635	2.21E+06

"1" = 1 dB down on both sides
"1.5" = 1 dB down on both sides

Table 2
EQUATIONS FOR COMPUTING THE LOSS FACTOR AND MODULUS OF DAMPING MATERIALS

Bare bar:

$$E = (12\,\rho\, l^4 f^2_n) / (H^2\, C^2_n)$$

where:

E	=Young's modulus of steel bar (bare bar), Pa,
ρ	= density of bare bar, kg/m^3,
l	= length of bar (same as free length L), m,
f_n	= the resonance frequency for mode n, Hz,
H	= thickness of bar in vibration direction, m,
n	= mode number: 1, 2, 3, ..., and
C_n	= coefficient for mode n, of cantilever bar,

where:

C_1= 0.55959, C_2= 3.5069, C_3= 9.8194, C_4= 19.242, C_5= 31.809, and $C_n = (\pi/2)(n-0.5)^2$, for n>3

Sandwiched Specimen (constrained layer) – Calculate the shear modulus and the loss factor of the damping material from the expressions:

$$G_2 = \left[\frac{(A-B)-2(A-B)^2-2(A\eta_s)^2}{\left((1-2A+2B)^2+4(A\eta_s)^2\right)}\right] * \left[\frac{2\pi C_n E H H_2}{l^2}\right]$$

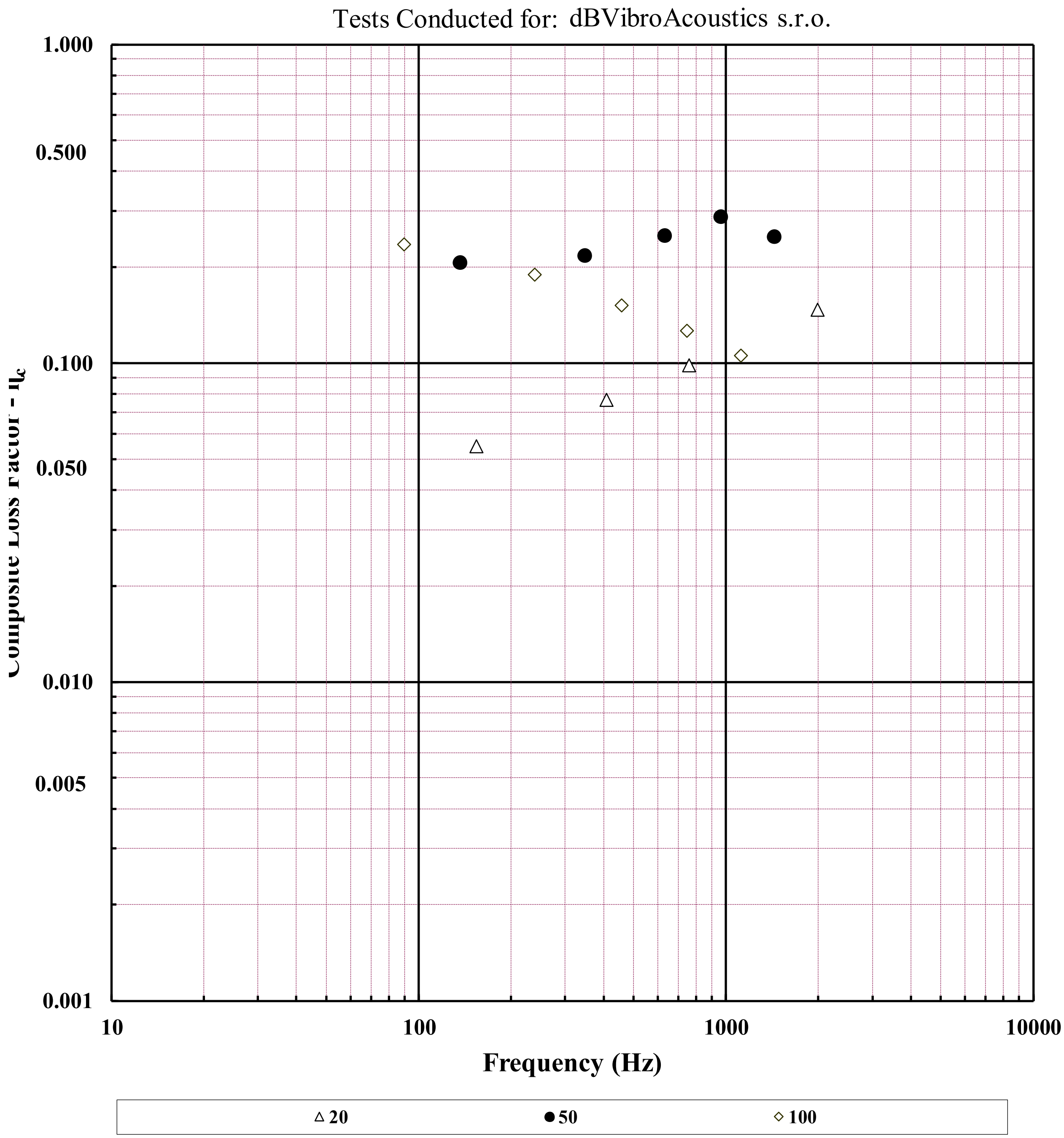
and

$$\eta_2 = \frac{A\eta_s}{\left(A-B-2(A-B)^2-2(A\eta_s)^2\right)}$$

where:

G	= shear modulus of damping material, Pa,
E	= Young's modulus of Oberst bar, Pa
f_n	= resonance frequency for mode n of Oberst bar, Hz
f_s	= resonance frequency for mode s of composite bar, Hz
s	= index number: 1, 2, 3, … ($s \equiv n$)
Δf_2	= half-power bandwidth for mode s of composite bar, Hz
η_s	= $\Delta f_s / f_s$, loss factor of sandwiched specimen, dimensionless
η_2	= shear loss factor of damping material, dimensionless
H_2	= thickness of damping material, m
H	= thickness of Oberst bar, m
T	= H_2/H, thickness ratio
l	= length of bar, m
ρ_2	= density of damping material, kg/m^3
ρ	= density of Oberst bar, kg/m^3
D	= ρ_2/ρ, density ratio
A	= $(f_s/f_n)^2(2+DT)(B/2)$
B	= $\dfrac{1}{6(1+T)^2}$
C_n	= coefficient for mode n, of cantilever bar (see Bare Bar)

COMPOSITE LOSS FACTOR FROM OBERST BAR DAMPING TESTS



Sample Description: S1: High Temp Damping #1 (6+26)

Meas. Sample Thickness: 0.1 mm

Meas. Sample Surf. Dens: 0.07 kg/m²