MATELYS
RESEARCH LAB

Report 201915 - 19-DB-12

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On request of
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Vibro
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Following purchase order 20190517-1P signed on May the 17th of 2019.

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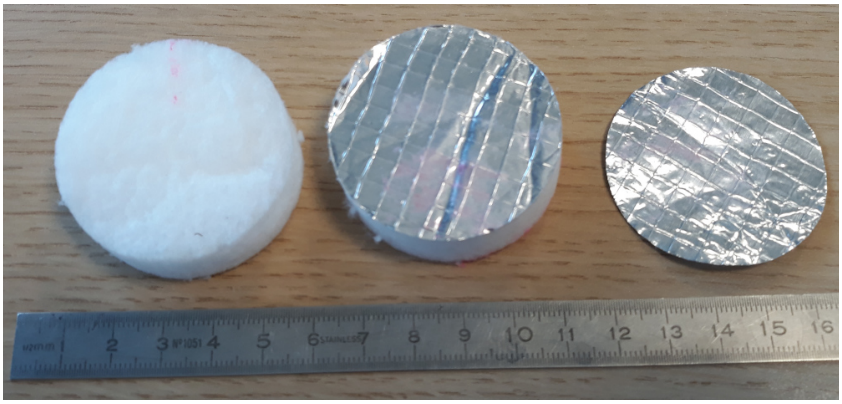

Figure 1: **DB 12** : Picture of material 12 composed by an aluminum facing screen on top of Melamine fibers. The mass density of the fibers is 24 ± 2 kg.m^{-3}. The thickness of the aluminum facing screen is around 402 ± 39 kg.m^{-3} with a thickness around 0.3 mm (i.e. a surfacic mass density of 122 ± 13 kg.m^{-2}). **The characterization results below are related to the Melamine fibers only.**

1.1 Static air-flow resistivity

The static air flow resistivity of the material has been estimated using the low asymptote approach as described in the appendix of ISO 9053-1:2018[1]. $\delta\sigma$ represents the standard deviation of each estimation for a given sample.

[1] ISO 9053-1. Acoustics – determination of airflow resistance – part 1: Static airflow method. *International Organization for Standardization*, 2018.

Test	σ ($\delta\sigma$)	*Thickness*
12 i a	43 500 (3 900)	15.7
12 ii a	40 700 (4 300)	15.7
12 iii a	38 300 (4 100)	15.6
Mean values (σ_X)	**40 800** (2 600)	**15.7** (0.1)
Units	N.s.m^{-4}	mm

Table 1: **DB 12 - fibers only**: Estimation results for the static air flow resistivity. Values for each tested sample, mean value and standard deviation (σ_X) over all samples.

The relative standard deviation of these static air-flow resistivities measurements is 6%.

1.2 Open porosity

The value of the open porosity has been estimated using the low asymptote approach as described in Jaouen et al. 2018 [2].$\delta\sigma$ represents the standard deviation of each estimation for a given sample.

[2] L. Jaouen, E. Gourdon, and M. Edwards. 6-parameter acoustical characterization of porous media using a classical impedance tube. In *Proc. of Euronoise 2018 (27-31 May, Hersonissos, Crete, Greece)*, 2018.

Test	ϕ (δ)
12 i a	0.98 (0.02)
12 ii a	0.98 (0.02)
12 iii a	0.98 (0.01)
Mean value (σ_X)	**0.98** (0.00)
Unit	

Table 2: **DB 12 - fibers only**: Estimation results for the open porosity. Values for each test, mean value and standard deviation (σ_X) over all tests.

One may note that the standard deviation over the measurements is equal to zero, however the precision of the method for such mean value is 2%.

1.3 Tortuosity, characteristic lengths and static thermal permeability

Estimations of the high frequency limit of the dynamic tortuosity, the characteristic viscous and thermal lengths and the static thermal permeability of the material have been realised from measured data of dynamic mass densities and compressibilities (see section **??**).

Test	α_∞ (δ)	$\mathbf{\Lambda}$ (δ)	$\mathbf{\Lambda'}$ (δ)	$\mathbf{k}'_0$ (δ)	*Thickness*
12 i a	1.04 (0.05)	42 (2)	44 (1)	23 (4)	15.7
12 ii a	1.08 (0.08)	32 (4)	69 (5)	42 (7)	15.7
12 iii a	1.08 (0.07)	51 (3)	61 (4)	41 (16)	15.6
Mean values (σ_X)	**1.07** (0.07)	**42** (10)	**58** (12)	**35** (14)	**15.7** (0.1)
Units		μm	μm	10^{-10}m^2	mm

Table 3: **DB 12 - fibers only**: Estimation of the acoustic parameters of the Johnson-Champoux-Allard-Lafarge model. Values for each tested sample, mean value and standard deviation (σ_X) over all samples.

1.3.1 Validation of the parameters

Fig. 2 compares the sound absorption coefficient as measured in the impedance tube and as computed using a Johnson-Champoux-Allard-Lafarge model (JCAL) according to the mean values of the parameters characterized above.

Measured data are represented as the dispersion envelope obtained over all characterized samples.

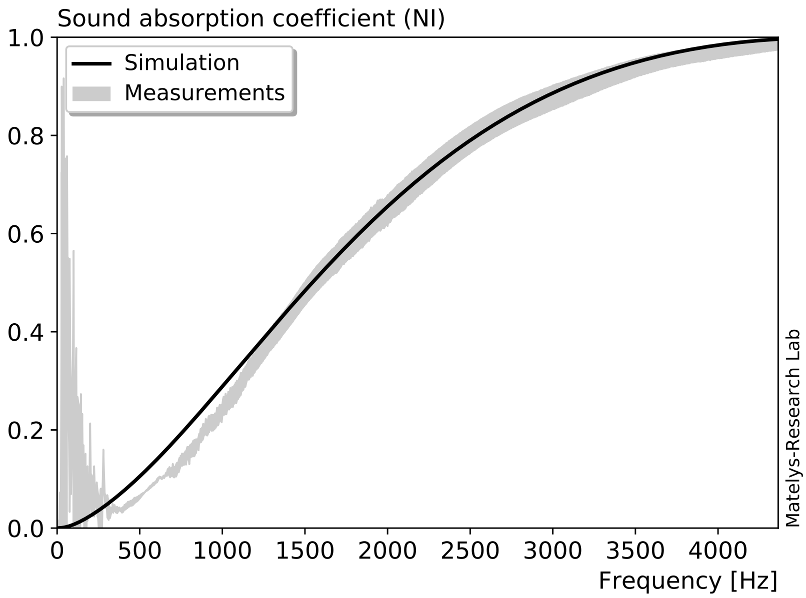

Figure 2: **DB 12 - fibers only** : sound absorption coefficient for plane waves under normal incidence (NI).
: dispersion over measured samples,
: simulation using the JCAL model,
Material backed with an impervious and rigid backing.
Temperature : 23°C
Ambiant pressure: 101 400 Pa
Hygrometry: 42%

The deviation between measurements and simulation at low frequencies is due to a small gradient of properties of the fibers through the thickness (the fibers in contact with the aluminum facing screen have a slightly higher density that the mean mass density).

1.4 Elastic parameters

The following table presents the elastic characterization results for samples of the fibers only under an uni-axial compression test (see section 3). The direction of the uni-axial compression is perpendicular to the fiber plan. Note that the Poisson's ratio studied during these uni-axial compression tests was equal or so close to close to 0 that it was not possible to differenciate it from 0 with respect to the accuracy of the method.

Test	**E**	η	ν	ρ
1	6.9	0.16	0.00	24
2	6.8	0.16	0.00	23
3	7.8	0.13	0.00	26
Mean values (σ_X)	**7.2** (0.6)	**0.15** (0.02)	**0.00** (0.00)	**24** (2)
Units	$\times 10^3$ N.m^{-2}			kg.m^{-3}

Conditions:

Temperature: 24 °C — Static stress $\sim$ 245 Pa
Ambiant Pressure: 101 450 Pa — Resonance freq. $\sim$ 25 Hz
Hygrometry : 43%

Table 4: **DB 12 - fibers only** : elastic and damping parameters of the tested material assumed to be isotropic. Values for each tested sample, mean value and standard deviation (σ_X) over all samples.

Part II
Description of the characterization techniques

2 Measuring the thickness of samples

The thicknesses of material samples are manually measured using an electronic calipers with a precision of 0.01 mm. for material samples which do not have a perfect flat surface, the thickness precision is 0.1 mm.

3 Estimating the elastic and damping parameters

The method used in this report is based on the study of the vibrations of a mass – spring system under an uni-axial compression test.

The measured Frequency Response Function (FRF) is defined as the ratio of the displacements of the top rigid mass to the base moving plate for a rectangular parallelepiped or cylindrical (with circular cross section) sample material (see Fig. 3). From a practical point of view, an accelerometer is used to determine the base plate displacement and a second one is used to determine the displacement of the top loading mass.

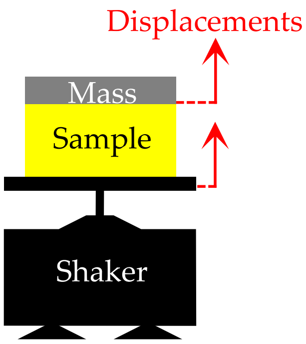

Figure 3: Scheme of the experimental setup used in the mass – spring resonance method.

This method can be used for the determination of the Young's modulus, the Poisson coefficient and the structural loss factor of an assumed isotropic material sample when the top loading mass is known. The analysis of the FRF in the vicinity of the resonance of the mass-spring system allows to determine the structural loss factor and the apparent Young's modulus. This latter modulus is linked to the actual Young's modulus of the material by a factor which depends on the shape of the sample and on the Poisson's ratio of the material. Thus, for a given shape factor[3], this coefficient only depends on the Poisson's ratio of the material [4]. Therefore, by testing samples having different shape factors, the Poisson's ratio can be estimated. Finally, from this latter value, the actual Young's modulus of the material can be determined.

[3] The shape factor is defined as the ratio between the sample volume and its free lateral surfaces.

[4] C. Langlois, R. Panneton, and N. Atalla. Polynomial relations for quasi-static mechanical characterization of isotropic poroelastic materials. *J. Acoust. Soc. Am.*, 110:3032–3040, 2001.

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