Dipartimento di Ingegneria
Università degli Studi di Ferrara
44100 Ferrara
Italy
Email : patrizio.fausti@unife.it

Contract Number: TCA5-CT-2006-031331

CANTOR
CoordinAting Noise TranspOrtation Research
and engineering solutions

Report on measurement methods for new materials

Deliverable 2.6 of the CANTOR project

Project Coordinator: Marcus Wallenberg Laboratory for Sound and Vibration Research KTH Sweden

Partners:		
	Chalmers (SE)	KU Leuven (BE)
	KTH (SE)	INSA (FR)
	ISVR (UK)	TUBerlin (D)
	UFerrara (I)	

Document identity : CANWP2TR2-180907-FER01
Date : 2008 – 10 – 31
Level of confidentiality : PU

Written by	Date (YY-MM-DD)	Reviewed by	Date (YY-MM-DD)
Patrizio Fausti	2008 – 10 – 20	Anders Nilsson	2008 – 10 – 30

Project funded by the EC under the Sixth Framework Programme

Priority 1.6.2 Sustainable Surface Transport

Preliminary Report on Deliverable 2.6

The objective of the Deliverable 2.6, entitled "Report on measurement methods for new materials", is to lists the measurement techniques on new materials available at the present.
The Deliverable 2.6 also aims at providing a web resource to facilitate cooperation between various research groups at universities, institutes and industries.
In fact for primary noise reduction to be effective the industry must have access to reliable prediction tools, test methods and databases on new materials as well as adequately trained personnel. Various types of novel prediction models and measurement techniques are continuously being developed at the major universities. Due to lack of resources these models are generally not fully developed or tested on general cases.

The current Deliverable is closely related to Deliverable 2.2, entitled 'Research facilities promoted on Web", Deliverable 2.3, entitled 'Report on current prediction models and techniques" and Deliverable 2.5, entitled 'Framework setting up new material database".
Through the objectives of those deliverables the available resources will be clear to industrial and scientific communities throughout Europe.

The University of Ferrara has coordinated the current Deliverable. In order to collect the information related to the test-rigs and methods, a webpage has been realized for collecting the measurement principle, the standard and the reference, in the case of non standardized techniques, and to give a short description the test-rigs together with their purpose.
In the following pages a collection of measurement methods will be reported as it has been published in the Cantor website:

http://www.cantor-online.net/wp2/task24/Task2.6/Task2.6/task26.html

WP 2.6 REPORT ON MEASUREMENT METHODS FOR NEW MATERIALS

Acoustical Properties
Physical Properties
Mechanical and Damping Properties

ACOUSTICAL PROPERTIES

Normal Incidence Surface Properties

Parameter	Normal incidence sound absorption coefficient and surface impedance
Principle/Standard /Reference	1. Pure tone method EN ISO 10534-1:2001 Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Part 1: Pure Tone method 2. Transfer Function Method EN ISO 10534-2:2001 Acoustics - Determination of sound absorption coefficient and impedance in impedance tubes - Part 2: Transfer-function method

Description:

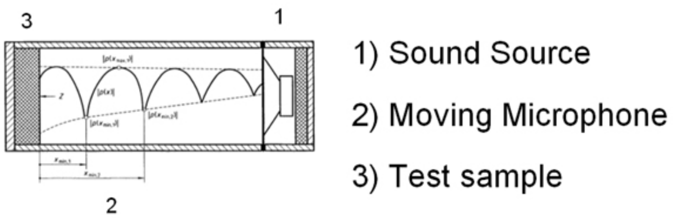
According to the standard EN ISO 10534-1 and 2 (2001), this method enables absorption coefficient and surface impedance to be measured. The apparatus consists of a tube of circular cross section whose terminations are equipped respectively with a loudspeaker on one hand and with the sample to be tested on the other.

EN ISO 10534-1 specifies a method for the determination of the sound absorption coefficient, reflection factor, surface impedance or admittance of materials and objects. The values are determined by evaluation of the standing wave pattern of a plane wave in a tube, which is generated by the superposition of an incident sinusoidal plane wave with the plane wave reflected from the test object.

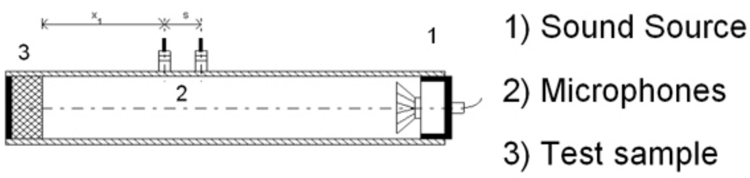
According to EN ISO 10534-2 by measuring sound pressure at two position in the tube and calculating their transfer function it is possible to solve equations for complex reflection coefficient and hence to get surface impedance and absorption coefficient.

Test-rig Scheme

Pure tone Method



Transfer Function Method



Diffuse Field Sound Absorption Coefficient

Parameter	Diffuse field sound absorption coefficient
Principle/Standard /Reference	ISO 354-1:2003 Acoustics -- Measurement of sound absorption in a reverberation room

Description:

ISO 354:2003 specifies a method of measuring the sound absorption coefficient of acoustical materials used as wall or ceiling treatments, or the equivalent sound absorption area of objects, such as furniture, persons or space absorbers, in a reverberation room. It is not intended to be used for measuring the absorption characteristics of weakly damped resonators.
The results obtained can be used for comparison purposes and for design calculation with respect to room acoustics and noise control.

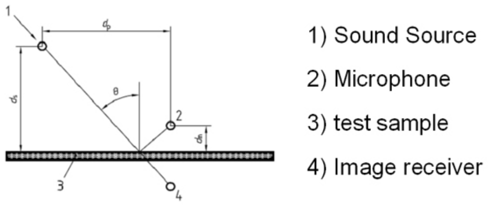
Normal and Oblique Incidence Sound Absorption Coefficient

Parameter	Sound absorption coefficient at normal and oblique incidence
Principle/Standard (reference)	ISO 13472-1:2002 Acoustics -- Measurement of sound absorption properties of road surfaces in situ -- Part 1: Extended surface method

Description:

This method is based on the measurement of the impulse response ; the suitable sounds (i.e. direct and reflected waves) are isolated by applying a special time window. In order to separate incident and reflected sound, the subtraction technique is used. The method allows the calculation of absorption and complex reflection coefficients for different angles of incidence. Practical working frequency range: 250-5000 Hz.

Test-rig Scheme



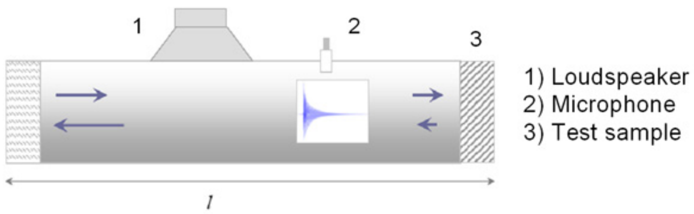
Normal Incidence Sound Absorption Coefficient

Parameter	Sound absorption coefficient at normal incidence
Principle/Standard /Reference	Reverberation Time method: N.Prodi et al. “A new apparatus for measuring the effective coupling of acoustic absorption of materials used inside cabins”, Proc. of SAE 2005 NOISE & VIBRATION CONFERENCE 2005

Description:

The device consists of a measurement tube with circular cross section which is equipped at both ends with sample holders. The sound power is injected by a small aperture on the side and the sound field is captured by a single microphone placed on the side as well. By calculation of the reverberation time inside the tube it is possible to derive the sound absorption coefficient for normal incidence both for a single and for a combination of two test samples.

Test-rig Scheme



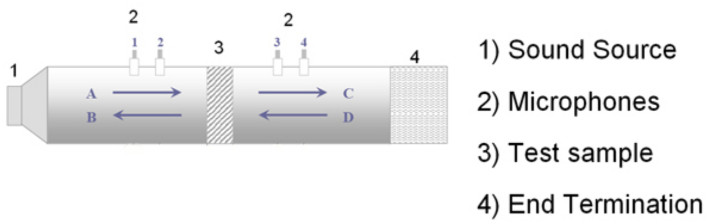
Normal Incidence Sound Transmission Loss

Parameter	Sound Transmission Loss at normal incidence in a plane wave tube
Principle/Standard /Reference	1. Transfer Matrix Method P. Bonfiglio et al. : *A SINGLE MEASUREMENT APPROACH FOR THE DETERMINATION OF THE NORMAL INCIDENCE TRANSMISSION LOSS*, J. Acoust. Soc. Am., 124(3), 1577-1583 (2008) 2. Transfer Matrix Method B. H. Song et al. “A transfer matrix approach for estimating the characteristic impedance and wave numbers of limp and rigid porous materials”, J.Acoust. Soc. Am., Vol.107 (3), pp. 1131-1152. (2000) 3. M. L. Munjal, A. G. Doige, ‘Theory of a Two Source-location Method for Direct Experimental Evaluation of the Four-pole Parameters of an Aeroacoustic Element’, Journal of Sound and Vibration, Vol. 141 (2), pp. 323-333. (1990) 4. T. Y. Lung, A. G. Doige, ‘A Time-averaging Transient Testing Method for Acoustic Properties of Piping Systems and Mufflers’, J. Acoust. Soc. Am., Vol. 73, pp. 867-876. (1983)

Description:

These techniques are based on the transfer matrix approach, using a 4 microphones technique. The sound field is decomposed into an incident, a reflected and a transmitted wave. The reflected contribution of the end termination is also accounted.

Test-rig Scheme



Diffuse Field Sound Transmission Loss

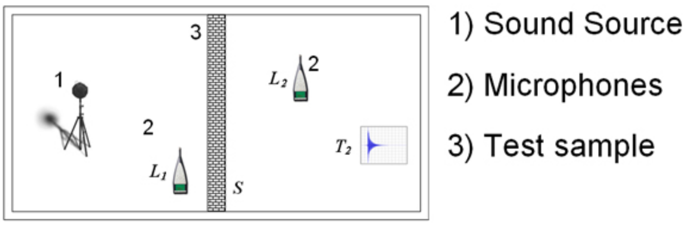
Parameter	Diffuse field sound Transmission Loss
Principle/Standard /Reference	1. ISO 140-3 & 4:1995 Acoustics -- Measurement of sound insulation in buildings and of building elements -- Part 3: Laboratory measurements of airborne sound insulation of building --Part 4: Field measurements of airborne sound insulation between rooms 2. ISO 15186-1 & 2:2000 & 2003 Acoustics -- Measurement of sound insulation in buildings and of building elements using sound intensity -- Part 1: Laboratory Measurement -- Part 2: Field measurements

Description:

1. Specify a laboratory and field method of measuring the airborne sound insulation of building elements such as walls, floors, doors, windows, facade elements and facades, except those classified as small building elements.
2. ISO 15186-1 & 2 specifies a sound intensity method to determine the sound insulation of walls, floors, doors, windows and small building elements. It is intended for measurements that have to be made in the presence of flanking transmission. It can be used to provide sound power data for diagnostic analysis of flanking transmission or to measure flanking sound insulation parameters.
ISO 15186-2:2003 can be used by laboratories that could not satisfy the requirements of ISO 15186-1, which deals with laboratory measurements with no or little flanking transmission. ISO 15186-3 deals with measurements under laboratory conditions, at low frequencies.
ISO 15186-2:2003 also describes the effect of flanking transmission on measurements made using the specified method, and how intensity measurements can be used :
-- to compare the in-situ sound insulation of a building element with laboratory measurements where flanking has been suppressed (i.e. ISO 140-3),
-- to rank the partial contributions for building elements, and
-- to measure the flanking sound reduction index for one or more transmission paths (for validation of prediction models such as those given in EN 12354-1).
The reproducibility of this intensity method is estimated to be equal to or better than that of the methods of ISO 140-10 and ISO 140-4, when measuring a single small and large building element, respectively.

Test-rig Scheme

ISO 140- 2 & 3



15186-1 & 2:

Complex Acoustical Parameters

Parameter	Acoustical Complex Parameters of porous materials (characteristic impedance, complex wave number, complex density, complex sound velocity, etc...)
Principle/Standard /Reference	1. Transfer Matrix Method • B. H. Song et al. "A transfer matrix approach for estimating the characteristic impedance and wave numbers of limp and rigid porous materials", J.Acoust. Soc. Am., Vol.107 (3), pp. 1131-1152. (2000) • Mcintosh J. D., Zuroski M.T. and Lambert R. F., "Standing wave apparatus for measuring of acoustic materials in air fundamental properties of acoustic materials in air", J.Acoust. Soc. Am. 88(4) pp.1929-1938 (1990).

2. Two cavity and two thickness method

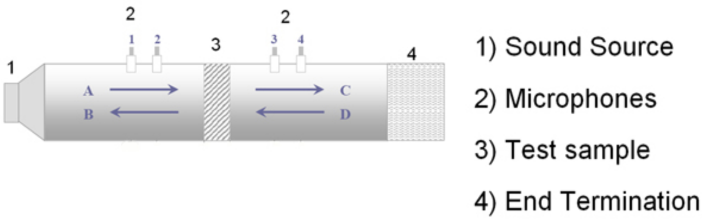
- M. A. Ferrero, G. Sacerdote, ‘Parameters of Sound Propagation in Granular Absorption Materials’, Acustica, 1, pp.135-142 (1951).
- H. Utsuno, T. Tanaka, T. Fujikawa, A. F. Seybert, ‘Transfer Function Method for Measuring Characteristic Impedance and Propagation Constant of Porous Materials’, J. Acoust. Soc. Am., Vol. 86 (2), pp. 637-643. (1989).

Description:

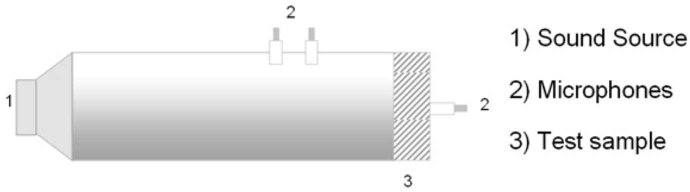
1. The knowledge of the complex properties of fibrous and porous materials has become of great importance in the design of quieter environments. This technique is based on the transfer matrix approach, using both 3 or 4 microphones techniques. The sound field is firstly decomposed into an incident, a reflected and a transmitted wave, and then the complex pressure and particle velocity at each side of the sample material are calculated. From these quantities the transfer matrix is obtained and finally the complex acoustical properties are calculated.
2. A classic impedance tube can be used for determining complex acoustical proper by means of two successive surface impedance measurements (both by considering two different air gaps or the same samples having different thickness)

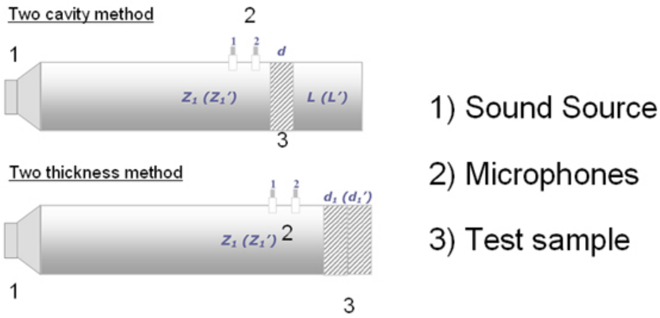
Test-rig Scheme

Transfer Matrix Method (4 microphones)



Transfer Matrix Method (3 microphones)





PHYSICAL PROPERTIES

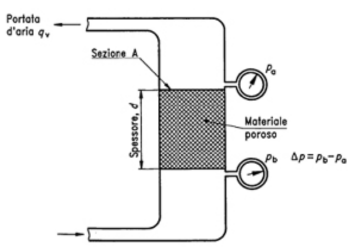
Airflow Resistivity

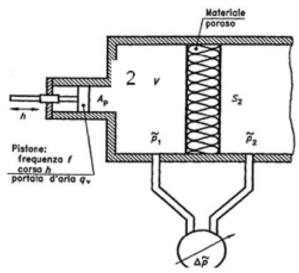
Parameter	Airflow resistivity of porous materials
Principle/Standard /Reference	ISO 9053:1991 Acoustics - Materials for acoustical applications - Determination of airflow resistance

Description:

The Flow Resistance is a measure of the resistance that air meets getting through a material. According to the Standard ISO 9053 a rigid piston is used to generate a low frequency (exactly 2 Hz) alternating airflow through the specimen. A condenser microphone is used to measure the rms pressure.

Test-rig Scheme





Open Porosity

Parameter	Open porosity of porous materials. Porosity is a measure of the fractional amount of air volume within the tested material.
Principle/Standard /Reference	1. Champoux Y., Stinson M. R. and Daigle G. A., Air-based system for the measurement of porosity, Journal of Acoustical Society of America 89 pp.910 (1991). 2. Panneton R., Gros E., “A missing mass method to measure the open porosity of porous solids”, ACTA Acustica united with Acustica, 19, pp. 342-348 (2005) 3. Fellah, Z. E. A., Berger, S., Lauriks, W., Depollier, C., Aristégui, C. and Chapelon, J. Y., Measuring the porosity and the tortuosity of porous materials via reflected waves at oblique incidence, Journal of Acoustical Society of America 113(5) pp.2424-2433 (2003). 4. Umnova O., Attenborough K., Shin H. and Cummings A., Deduction of tortuosity and porosity from acoustic reflection and transmission measurements on thick samples of rigid-porous materials, Applied Acoustics 66 pp.607-624 (2005).

Description:

1. The method is based on Boyle’s Law, using isothermal compression of air volume within and external to the materials.

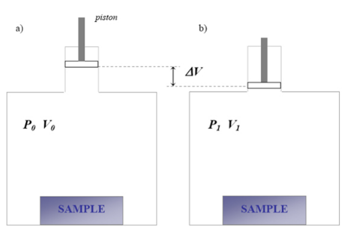
2. The method permits to measure the open porosity of porous solids when the mass density of the solid phase constituent is unknown. In this case, the determination of the open porosity requires the determination of the volume of the solid phase. The proposed method is based on the measurement of the apparent (in-air) and true (in-vacuum) masses of a porous solid, where an in-air missing mass is found and related to the volume of the solid phase through the Archimedes' principle.

3. The proposed method is based on measurement of reflected wave by the first interface of a slab of rigid porous material. This method is obtained from a temporal model of the direct and inverse scattering problems for the propagation of transient ultrasonic waves in a homogeneous isotropic slab of porous material having a rigid frame [Z. E. A. Fellah, M. Fellah, W. Lauriks, and C. Depollier, J. Acoust. Soc. Am. 113, 61 (2003)]. Reflection and transmission scattering operators for a slab of porous material are derived from the responses of the medium to an incident acoustic pulse at oblique incidence. The porosity and tortuosity are determined simultaneously from the measurements of reflected waves at two oblique incidence angles. Experimental and numerical validation results of this method are presented.

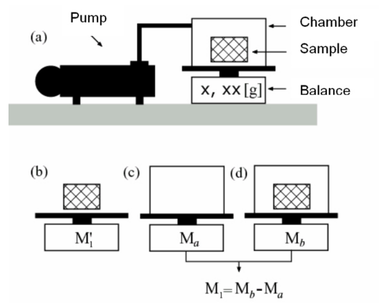
4. The method uses pulses with central frequencies close to 12 kHz and an approximate bandwidth of between 3 and 20 kHz. In this frequency range, inertial rather than viscous or scattering effects dominate sound propagation in large pores. This allows application of the high frequency limit of the “equivalent fluid” model. Both reflected and transmitted signals are used in the measurements. Tortuosity is deduced from the high frequency limit of the phase speed (obtained from transmission data) and porosity is obtained from the high frequency limit of the reflection coefficient once the tortuosity is known. The method is shown to give good results in the cases where significant scattering does not occur until frequencies much higher than the upper limit of the pulse bandwidth.

Test-rig Scheme

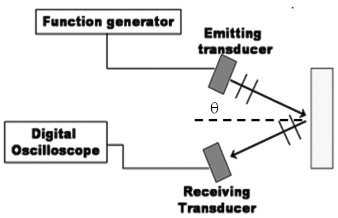
1) <u>Isothermal compression of air volume</u>



2) <u>Missing Mass Method</u>



3) <u>Ultrosonic method</u>



Tortuosity

Parameter	Tortuosity of porous materials. The tortuosity is an important parameter which intervenes in the description of the complexity of the path of the sound wave propagating within a material
Principle/Standard /Reference	1. Brown R., Connection between the formation factor for electrical resistivity and fluid-solid coupling factors in Biot's equations for acoustic waves in fluid-filled porous media, Geophysics 45 pp.1269-1275 (1980) 2. Allard J. F., Castagnède B., Henry M. and Lauriks W., Evaluation of the tortuosity in acoustic porous materials saturated by air, Review of Scientific Instruments 65 pp. 7654-755 (1994) 3. Fellah, Z. E. A., Berger, S., Lauriks, W., Depollier, C., Aristégui, C. and Chapelon, J. Y., Measuring the porosity and the tortuosity of porous materials via reflected waves at oblique incidence, Journal of Acoustical Society of America 113(5) pp.2424-2433 (2003). 4. Umnova O., Attenborough K., Shin H. and Cummings A., Deduction of tortuosity and porosity from acoustic reflection and transmission measurements on thick samples of rigid-porous materials, Applied Acoustics 66 pp.607-624 (2005).

Description:

1. The method is based on the measurement of electrical resistivity through a test sample.

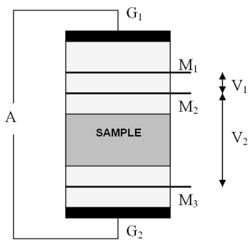
2. The method is based on determination of the high frequency limit for the complex phase velocity. The transmitted ultrasonic signal from a porous layer is measured in frequency domain. The phase velocity is calculated from the phase difference of the signals obtained with and without sample.

3. The proposed method is based on measurement of reflected wave by the first interface of a slab of rigid porous material. This method is obtained from a temporal model of the direct and inverse scattering problems for the propagation of transient ultrasonic waves in a homogeneous isotropic slab of porous material having a rigid frame [Z. E. A. Fellah, M. Fellah, W. Lauriks, and C. Depollier, J. Acoust. Soc. Am. 113, 61 (2003)]. Reflection and transmission scattering operators for a slab of porous material are derived from the responses of the medium to an incident acoustic pulse at oblique incidence. The porosity and tortuosity are determined simultaneously from the measurements of reflected waves at two oblique incidence angles. Experimental and numerical validation results of this method are presented.

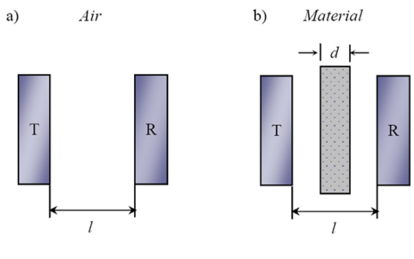
4. The method uses pulses with central frequencies close to 12 kHz and an approximate bandwidth of between 3 and 20 kHz. In this frequency range, inertial rather than viscous or scattering effects dominate sound propagation in large pores. This allows application of the high frequency limit of the "equivalent fluid" model. Both reflected and transmitted signals are used in the measurements. Tortuosity is deduced from the high frequency limit of the phase speed (obtained from transmission data) and porosity is obtained from the high frequency limit of the reflection coefficient once the tortuosity is known. The method is shown to give good results in the cases where significant scattering does not occur until frequencies much higher than the upper limit of the pulse bandwidth.

Test-rig Scheme

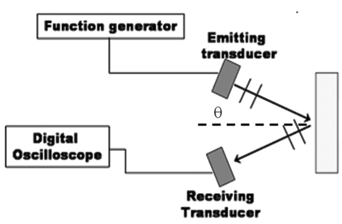
1) Electrical resistivity method



2) Ultrosonic method



3) Ultrosonic reflected wave method



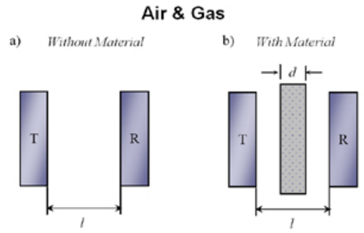
Viscous and Thermal Characeristic Lengths

Parameter	Viscous and thermal lengths of porous materials. These two parameters characterize the viscous and the thermal interactions between the frame and the fluid at high frequencies.
Principle/Standard /Reference	Leclaire P., Kelders L., Lauriks W., Melon M., Brown N., and Castagnède B., Determination of the viscous and thermal characteristic lengths of plastic foams by ultrasonic measurements in helium and air, Journal of Appled Physics 80 (1996).

Description:

According to this method, the air saturating the sample is replaced by helium and the transmission is studied at ultrasonic frequencies (70-600 kHz). The experiment is quite easily performed using standard ultrasonics and vacuum equipment. The main purpose of the method is to propose a method to determine simultaneously both the viscous and thermal characteristic lengths with the same precision. The characteristic lengths are deduced from the high-frequency asymptotic behavior of either the velocity or the attenuation curves obtained in the sample saturated by air and by helium.

Test-rig Scheme



MECHANICAL PROPERTIES

Mechanical properties of homogeneus and composite beams

Parameter	Mechanical properties of homogeneous (Young Modulus and Loss factor) and sandwich (Total Loss factor,Young modulus of the laminate and shear modulus of the core) structures
Principle/Standard /Reference	Free-Free suspended beam - Homogeneous structures : UNI-EN-ISO-6721 - Sandwich structures : D. Backstrom, "Modelling the flexural dynamics of sandwich beams using Bernoulli–Euler or Timoshenko theory with frequency dependent parameters", KTH, Stockholm, Sweden, TRITA-AVE 2004:45 ISSN 1651-7660, 2004.

Description:

The experimental procedure is based on the measurement of frequency response of an accelerometer mounted on the tested beam that is excited by using an impact hammer.
In order to obtain values for the mechanical parameters of the homogeneous beams (i.e. Young modulus) and the sandwich structures components (i.e. Young modulus of the laminates and shear modulus of the core), measurements on the beams with accelerometer and impact source at the different ends were carried out.

Mechanical properties of poro-elastic materials

Parameter	Mechanical properties of poro-elastic materials (Young Modulus, Poisson Ratio and Loss factor)
Principle/Standard /Reference	1. Quasi-static compression and lateral deformation E. Mariez, S. Sahraoui, and J. F. Allard, "Elastic constants of polyurethane foam's skeleton for Biot model" Proceedings of Internoise 96, pp. 951–954 (1996). 2. Quasi-static compression and polynomial relations Langlois C, Panneton R, Atalla N "Polynomial relations for quasi-static mechanical characterization of isotropic poroelastic materials" The Journal of the Acoustical Society of America - December 2001 - Volume 110, Issue 6, pp. 3032-3040 3. Quasi-static torsional method Etchessahar M, Benyahia L, Sahraoui S, Tassin J-F. Frequency dependence of elastic properties of acoustics foams. The Journal of the Acoustical Society of America 117 (2005). 4. T. Pritz, Dynamic Young's modulus and loss factor of plastic foams for impact sound isolation, J. Sound Vib. 178, pp. 315–322, (1994). 5. ASTM E756-98, Standard test method for measuring vibration-damping properties of materials (American Society for Testing and Materials, 1998). 6. Allard J-F, Henry M, Boeckx L, Leclaire P, Lauriks W. Acoustical measurement of the shear modulus for thin porous layers. J Acoust Soc Am 2005;117:1737–43. 7. Boeckx L, Leclaire P, Khurana P, Glorieux C, Lauriks W, Allard J-F. Guided elastic waves in porous materials saturated by air under lamb conditions. J Appl Phys 2005;97:094911.

Description:

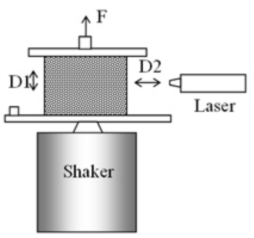
1. The elastic characterization is realized in two steps. First, the imposed displacement and an induced transverse displacement by Poisson's effect in a perpendicular direction are measured (by means of a laser vibrometer for this latter). This first step allows an estimation of this Poisson's ratio. Second, a measurement of the stiffness of the sample is done from the measured compression force and the imposed displacement. The complex Young's modulus, in the direction of the uniaxial compression, E is estimated by use of an inverse method based on precomputed results of a static three-dimensional solid finite element code . The measurement operation can however be repeated changing the observation direction for the measurement of Poisson's ratios and the uniaxial compression direction to estimate the complex Young's moduli in the three-dimensional space.
2. The method for determining mechanical properties is based on the measure of the mechanical stiffness of two disc shaped samples of

different diameters and the use of polynomial relations for simultaneously calculating Young’s modulus, Poisson ration and loss factor.

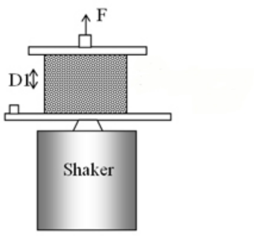
3. A nonresonance technique (dynamic stiffness) based on a forced vibrations procedure is used to investigate the frequency dependent complex shear modulus of a foams. This modulus is first measured, in a quasistatic configuration, in the frequency range (0.016–16 Hz) at different temperatures between 0 and 20 °C. It is afterwards predicted over a wide frequency range (0.01–3000 Hz) using the frequency-temperature superposition principle. The validation of this principle is discussed through quasistatic experiments. Under the assumption that Poisson's ratio of polymeric foams is real and frequency independent on the frequency range used, the frequency dependence of the complex shear modulus obtained is used to predict the complex stiffness of the acoustic foam on a wide frequency range.
4. The method is based on the determination of Young modulus and loss factors of prismatic long samples subjected to longitudinal exitacions
5. This test method measures the vibration-damping properties of materials, including loss factor, [eta], Young's modulus, E, and shear modulus, G. Accurate over a frequency range of 50 to 5 kHz and over the useful temperature range of the material, this test method is useful in testing materials that have application in structural vibration, building acoustics, and the control of audible noise. Such materials include metals, enamels, ceramics, rubbers, plastics, reinforced epoxy matrices, and woods that can be formed to the test specimen configurations.
6. Simulations performed with the Biot theory show that for thin porous layers, a shear mode of the structure can be induced by a point-source in air located close to the layer. The simulations show that this mode is present around frequencies where the quarter wavelength of the shear Biot wave is equal to the thickness of the samples and show that it can be acoustically detected from the fast variations with frequency of the location of a pole of the reflection coefficient close to grazing incidence. The strong coupling of the shear mode with the acoustic field in air allows the measurement of the shear modulus without mechanical excitation.
7. The propagation of guided elastic waves in porous materials saturated by air under Lamb conditions is studied theoretically and experimentally. The modes are derived from expressing the boundary conditions on the normal and tangential stresses and the displacements at the interfaces between the porous layer and the surrounding fluid. The stresses and the fluid pressure inside the porous medium are obtained from Biot's equations of poroelasticity. Symmetrical and antisymmetrical modes are found when the porous layer is loaded by the same fluid on both sides. Damping mechanisms include viscous and thermal exchanges between the solid and the fluid, in addition to the classical structural damping. Using an experimental setup based on the generation of standing waves in the layer and taking the spatial Fourier transform of the displacement profile, the phase velocities of three modes were measured for two porous materials in a frequency range between 80 Hz and 4 kHz. The measurements confirm the theoretical predictions and provide information on the shear modulus of a sound-absorbing material in a wide frequency range.

Test-rig Scheme

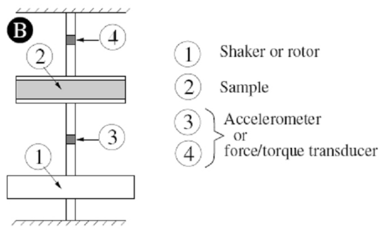
1. Quasi-static compression and lateral deformation



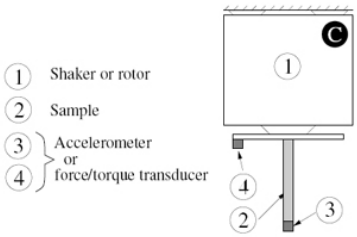
2. Quasi-static compression and polynomial relations



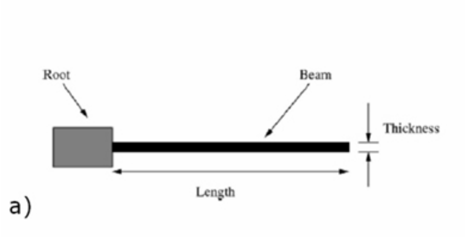
3. Quasi-static torsional method



4. Long samples subjected to longitudinal exitacions



5. ASTM E756-98



Mechanical properties of rubber materials

Parameter	Complex dynamic shear modulus, *G** and loss factor, *h* of rubber samples
Principle/Standard /Reference	The tests are performed dynamically and the complex shear modulus, *G**, is measured under low amplitude excitation at high frequency. The loss factor can be derived from the phase angle of the modulus.

Description:

An electrodynamic shaker (coil and magnet) is used to excite samples of viscoelastic material in shear. Four identical samples are held between a central steel shaft and an outer steel yoke. A bolt, connected to the yoke on either side, allows a small pre-compression to be applied.

Dynamic Stiffness

Parameter	Dynamic stiffness
Principle/Standard /Reference	1. ISO 9052-1:1989 Acoustics -Determination of dynamic stiffness - Part 1: Materials used under floating floors in dwellings 2. Sine vibration amplitude controlled excitation; dynamic stiffness extraction from 1DOF system assumption. S.Gade, K.Zaveri, H. Kostantin-Hansen, H.Herlufsen, "Complex Modulus and Damping Measurements using Resonant and Non-Resonant Methods". Bruel & Kjaer, 2000

Description:

1. The dynamic stiffness of a resilient material is the ratio of the dynamic force over the displacement produced. According to the ISO Standard ISO 9052-1, it is measured the resonance frequency of the system consisting of the resilient layer together with a steel mass when a dynamic force is applied to the steel mass. The Standard therefore implies that the model for the dynamic stiffness measurement is that of a simple one degree-of-freedom (1DOF) system, it can thus can be seen as a first approximation method for the estimation of a resilient material's dynamic stiffness.
2. Dynamic stiffness measurements of rubber samples as a function of prestrain and dynamic amplitude.

Test-rig Scheme