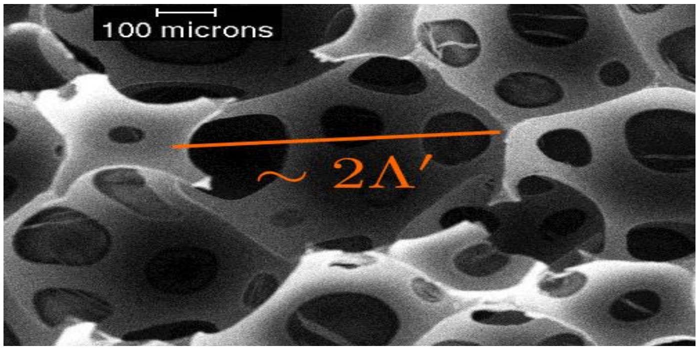
THERMAL CHARACTERISTIC LENGTH ESTIMATION

The thermal characteristic length Λ', related to the size pores, cannot be directly measured. An estimation of its value for a given porous material can be obtained from (i) the analysis of 2D or 3D acquisitions of the material microstructure, (ii) measurements in a standing wave tube at audible frequencies or (iii) measurements at ultrasonic frequencies.

Optical methods

The thermal characteristic length is, by definition, a scalar quantity. For spherical pores, the value of Λ' is close to the value of the radius of the pore. Thus, from 2D or 3D acquisitions of the material microstructure, an estimation of the thermal characteristic length can be obtained.

The main difficulty encountered with these methods is to define a macroscopic single value (or mean value), Λ', from a disperse microscopic information.

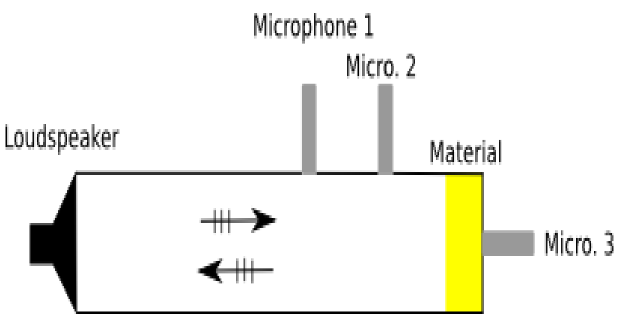


Scanning Electron Microscope picture of a polyurethane foam and estimation of the thermal characteristic length from this 2D picture acquisition. Photo by Luc Jaouen & Franck Paris.

Estimation method at audible frequencies

An estimation of the thermal characteristic length, Λ', can be obtained from the measurements of the dynamic density of a porous medium with prior knowledge of the static air flow resistivity and the open porosity. The method, introduced by Olny, Panneton & Tran-van *[OPT02]* and further described by Olny & Panneton *[0P08]* allows estimations of the viscous characteristic length, the high frequency limit of the dynamic tortuosity and the static thermal permeability from the same data.

The method is based on an analytical inversion of the formula for the dynamic mass density $\tilde{\rho}(\omega)$ following Champoux-Allard-Lafarge model*[CA91,LLAT97]* (see e.g. "Thermal effects" section for Johnson-Champoux-Allard-Lafarge model).



Top: schematic representation of the standing wave tube used to estimate the thermal and viscous characteristic lengths together with the tortuosity and static thermal permeability as described in *[OPT02]*,*[OP08]*.

Bottom: picture of such a tube with an internal diameter of 46 mm.

The drawbacks of this method is its sensibility to boundary conditions at the circumference of the material sample. If the material sample has a radius a bit larger than the radius of the impedance tube the material sample is compressed and its microstructure can be consequently modified. If the radius of the material sample is a bit smaller than the one of the tube, air-leakage can influence the inversion procedure and can lead to erroneous values for the parameters. In this latter case, a pressure diffusion effect can appear as in double porosity media.

Estimation from ultrasound measurements

in 1996, Leclaire et al. *[LKLBMC96]* introduced a method to estimate the thermal characteristic length Λ', together with the viscous characteristic length Λ from ultrasonic measurements (i.e. at frequencies higher than 20k Hz or at acoustic wavelengths smaller than $\sim$ 1.7 mm).

The method described by Leclaire et al. required the fluid phase of the porous medium to be successively saturated by air and helium.

From the measurements with these two fluids, it is possible to qualify the dissipation of the acoustic energy due to visco-inertial effects (characterized by Λ at high frequencies) and due to the Rayleigh scattering occuring when the acoustic wavelength is higher than the characteristic size of porous microstructure without being much greater than it.

In 2010, inspired by the work of Olny & Panneton, Groby et al. *[GORSL10]* proposed a method to estimate the thermal characteristic length together with the viscous characteristic length, the open porosity and the high frequency limit of the dynamic tortuosity from ultrasonic measurements fo the reflection and transmission coefficients. This method does not require the prior knowledge of the static air flow resistivity. However it cannot be used to estimate the static thermal peremability.

The drawbacks of these ultrasonic methods are the unknown effect, a-priori, of the Rayleigh scattering. In the work by Groby et al., this effect can lead to erroneous values for the parameters. In the work by Leclaire et al., the Rayleigh scattering effect can be qualified but measurements have been done twice (in two different saturating fluids).

Source: http://apmr.matelys.com/Parameters/Characterization/Acoustics/ThermalCharacteristicLength.html#Kundttube