

ADVANCES IN THE MICROSTRUCTURE AND TRANSPORT PROPERTIES OF RANDOM FIBROUS MATERIALS

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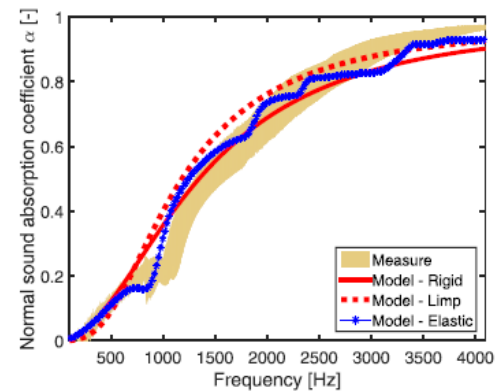
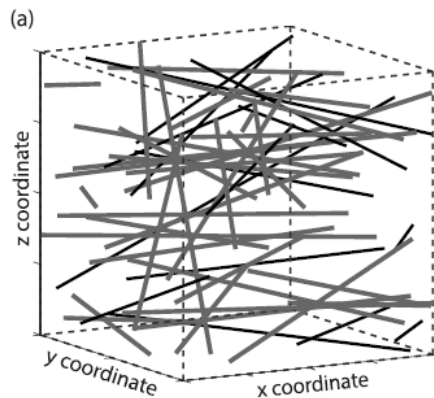
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- **Motivation.** The ability of air-saturated fibrous media to mitigate sound waves in controlled by their transport properties.
- **Objective.** Propose micro-/macro relationships to link microstructural features to macroscopic transport properties (random fiber structures).
- **Methodology.**
 - 1) **Generate** representative elementary volumes (**REV**) of random fiber structures (scale separation, rigid frame, overlapping fiber assumptions).
 - 2) **Transport equations** are numerically solved.
 - 3) **Micro-/macro** relationships are derived.



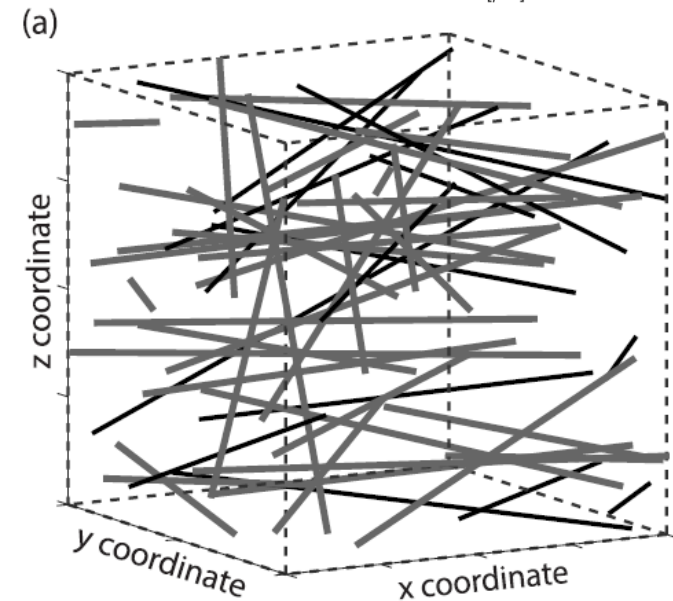
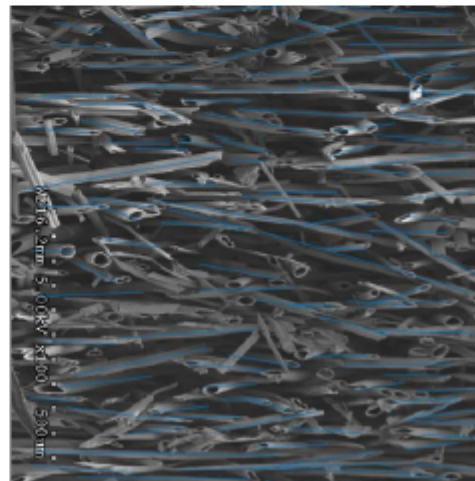
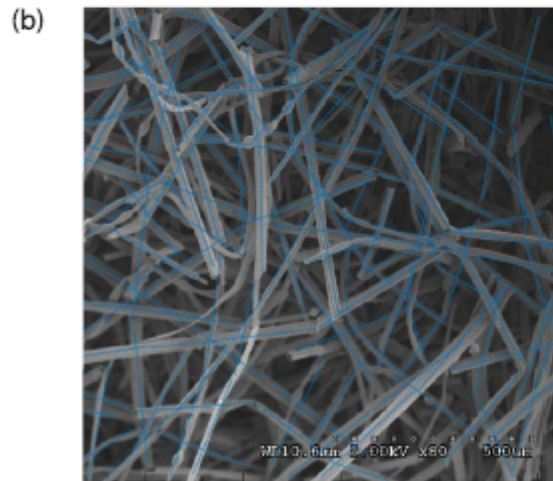
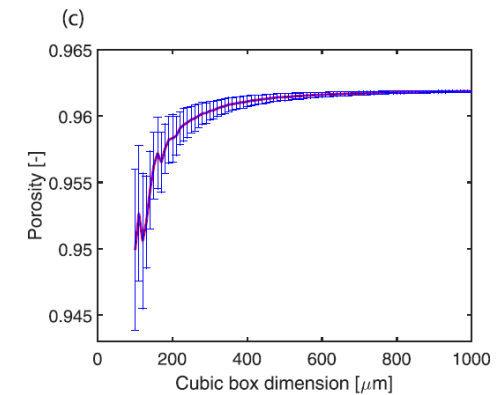
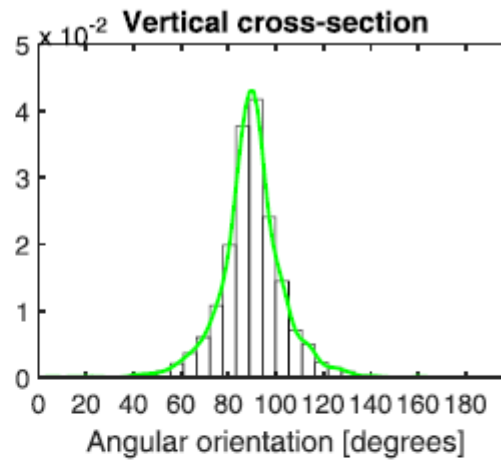
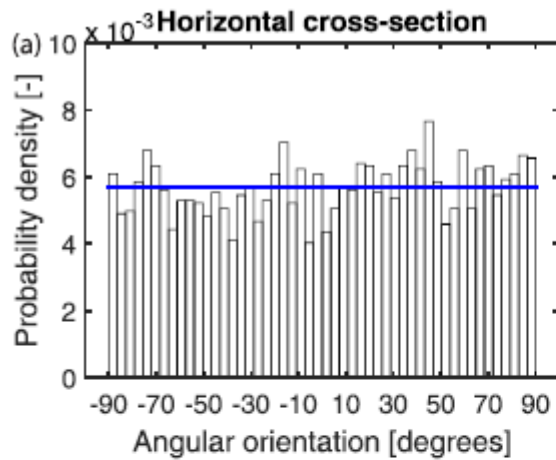
I. Procedure

A) Acquisition and Reconstruction

Advances in Random Fibrous Materials

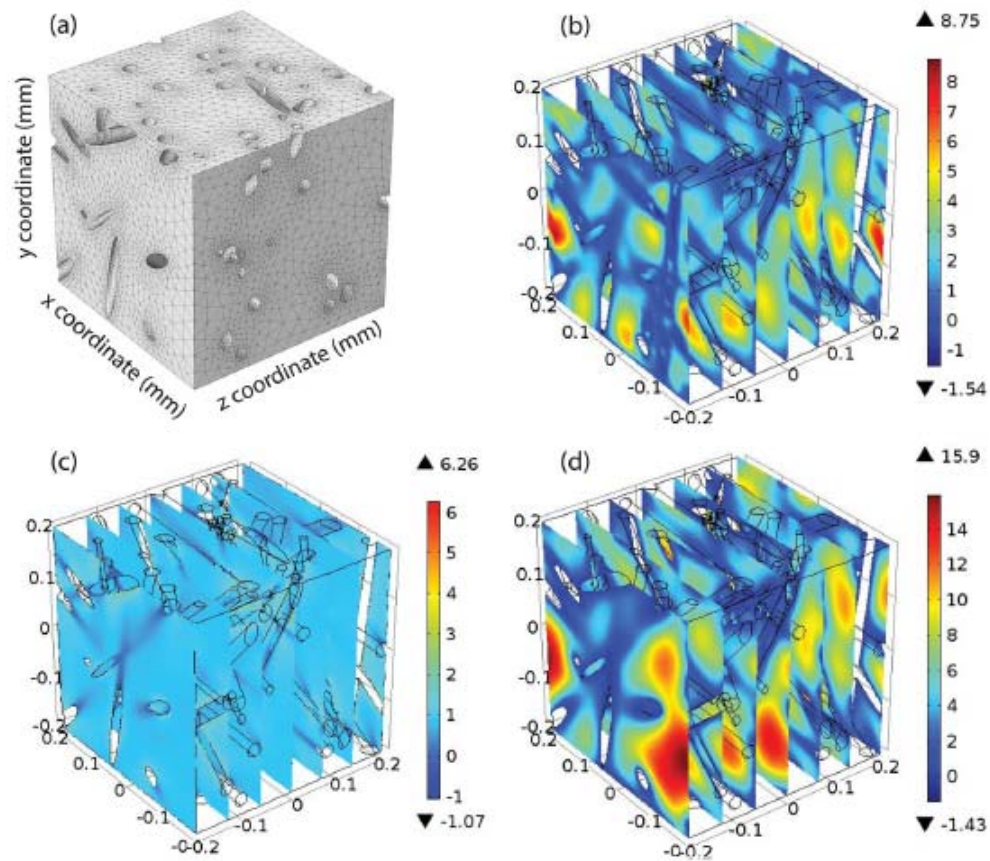
A procedure for the reconstruction of the 3D geometry of a random fibrous medium and its experimental validation

A) Acquisition and Reconstruction



A procedure for the reconstruction of the 3D geometry of a random fibrous medium and its experimental validation

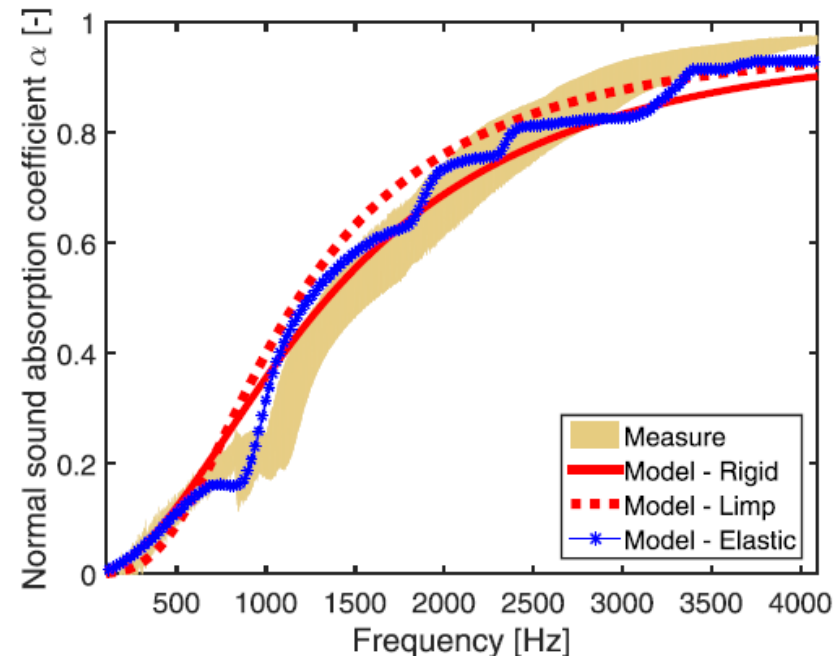
B) From three-dimensional geometry to transport and sound absorbing properties



A procedure for the reconstruction of the 3D geometry of a random fibrous medium and its experimental validation

C) Comparison with experimental data

	$\phi(-)$		$\Lambda'(\mu\text{m})$	$\alpha_\infty (-)$	$\Lambda (\mu\text{m})$	$k_0 (\times 10^{-11} \text{ m}^2)$	$k'_0 (\times 10^{-11} \text{ m}^2)$
	hollow fibers, ϕ_h	solid fibers, ϕ_s					
Measurements	0.962 ± 0.004					19.571 ± 1.184	
Computations	0.963 ± 0.003	0.900 ± 0.003	103 ± 4	1.054 ± 0.003	51 ± 2	19.247 ± 0.892	61.838 ± 5.848



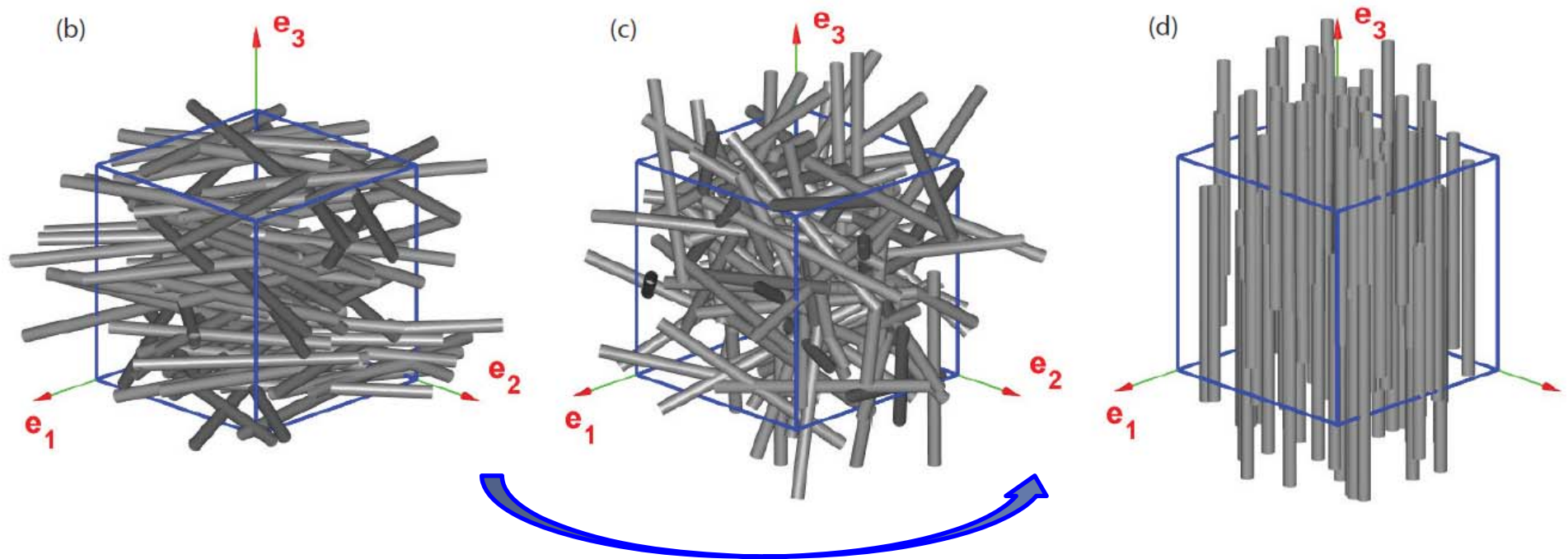
II. Computations

A) Parameters of the geometry

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Computations of the transport parameters over a wide range of variation of the geometric parameters

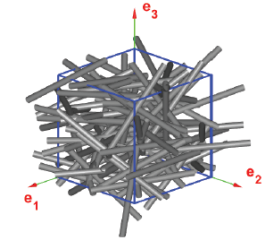
A) Parameters of the local geometry model



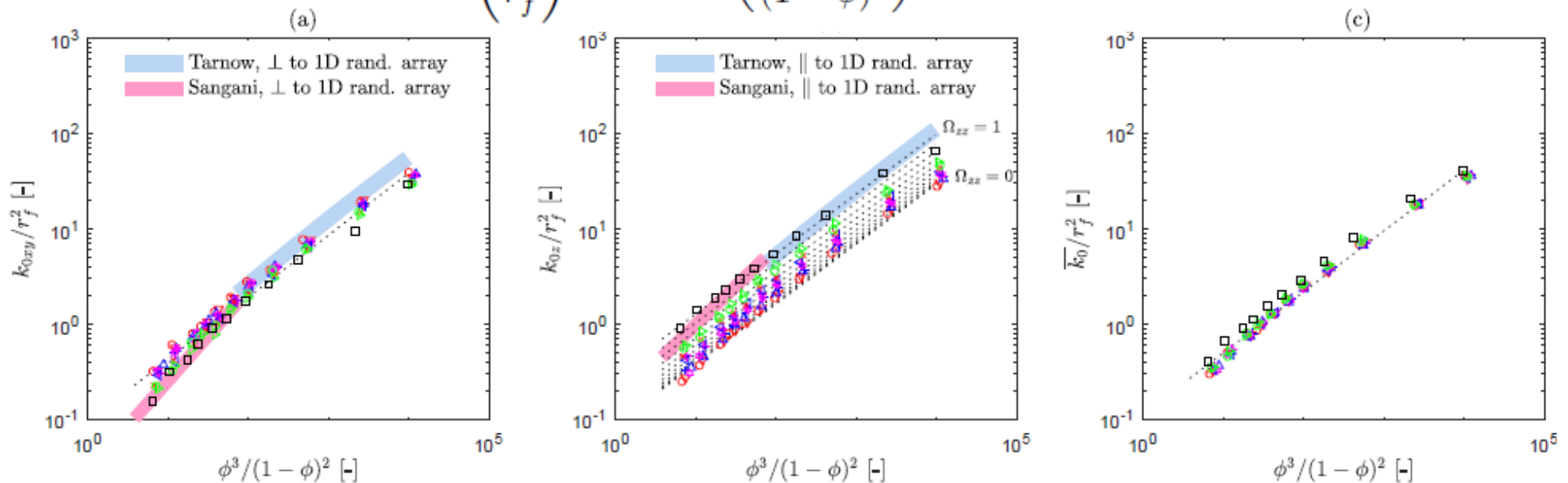
[H. T. Luu, C. Perrot, R. Panneton, "Influence of porosity, fiber radius and fiber orientation on the transport and acoustic properties of random fiber structures" Acta Acustica united Ac. 103, 1050 (2017)]

Correlation proposed to approximate these properties when the geometry is known

1st Example: Static viscous permeability

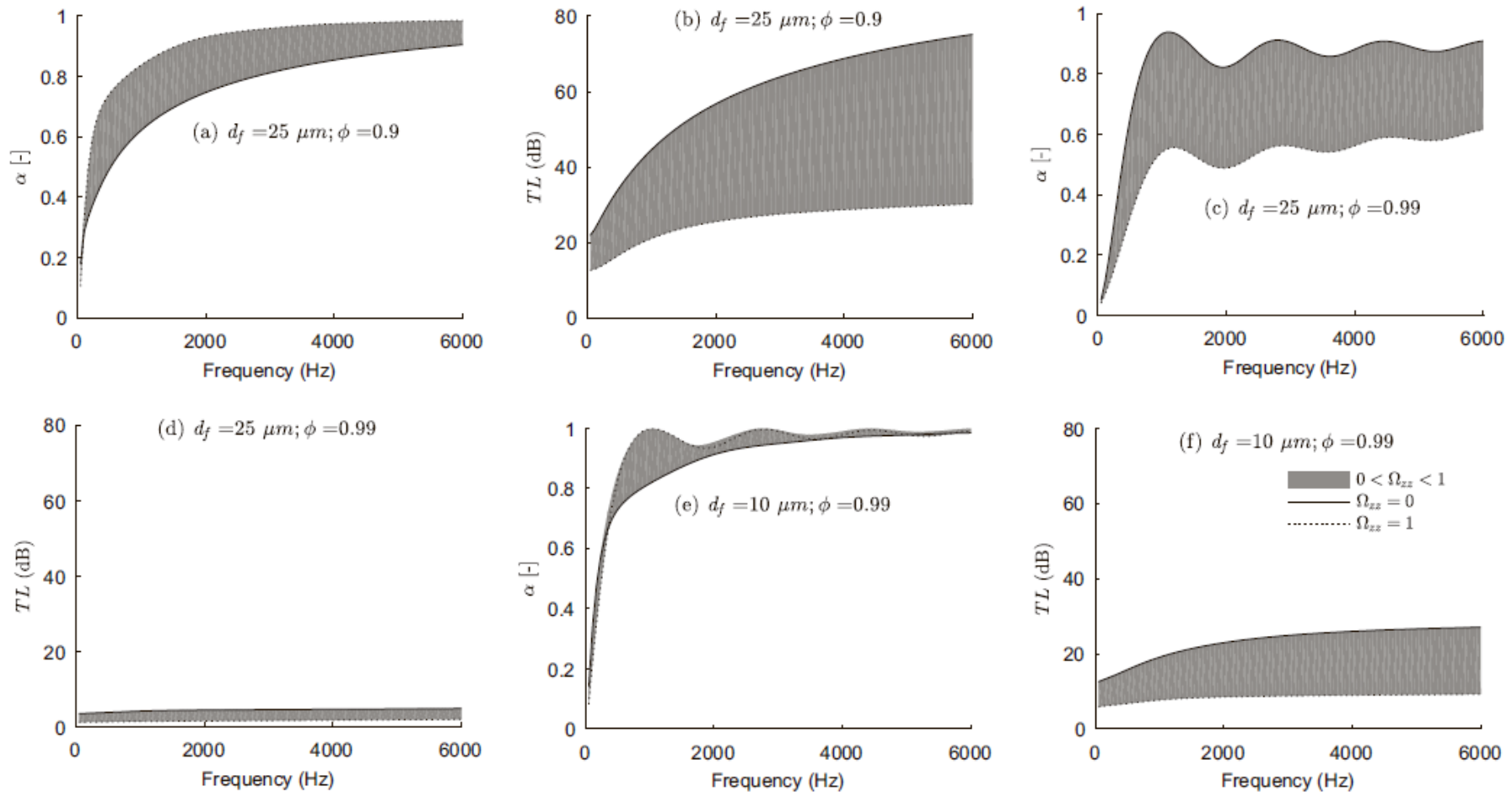


Simulations fit with
$$\log_{10} \left(\frac{k_0}{r_f^2} \right) = A \log_{10} \left(\frac{\phi^3}{(1-\phi)^2} \right) + B \Omega_{zz}^2 + C \Omega_{zz} + D$$



- ✓ The through plane permeability k_{0z} is more sensitive to fiber orientation Ω_{zz} than the in-plane permeability k_{0xz} :
 - (a) k_{0xy} varies linearly with $\phi^3/(1-\phi)^2$, which is consistent with the KC Eq.
 - (b) k_{0z} also depends on Ω_{zz} .

Effect of the orientation of fibers on the sound absorption and transmission loss



Substituting a polydisperse distribution of the fiber diameters by an equivalent monodisperse one?

A) Polydisperse fiber distribution (PDFD)

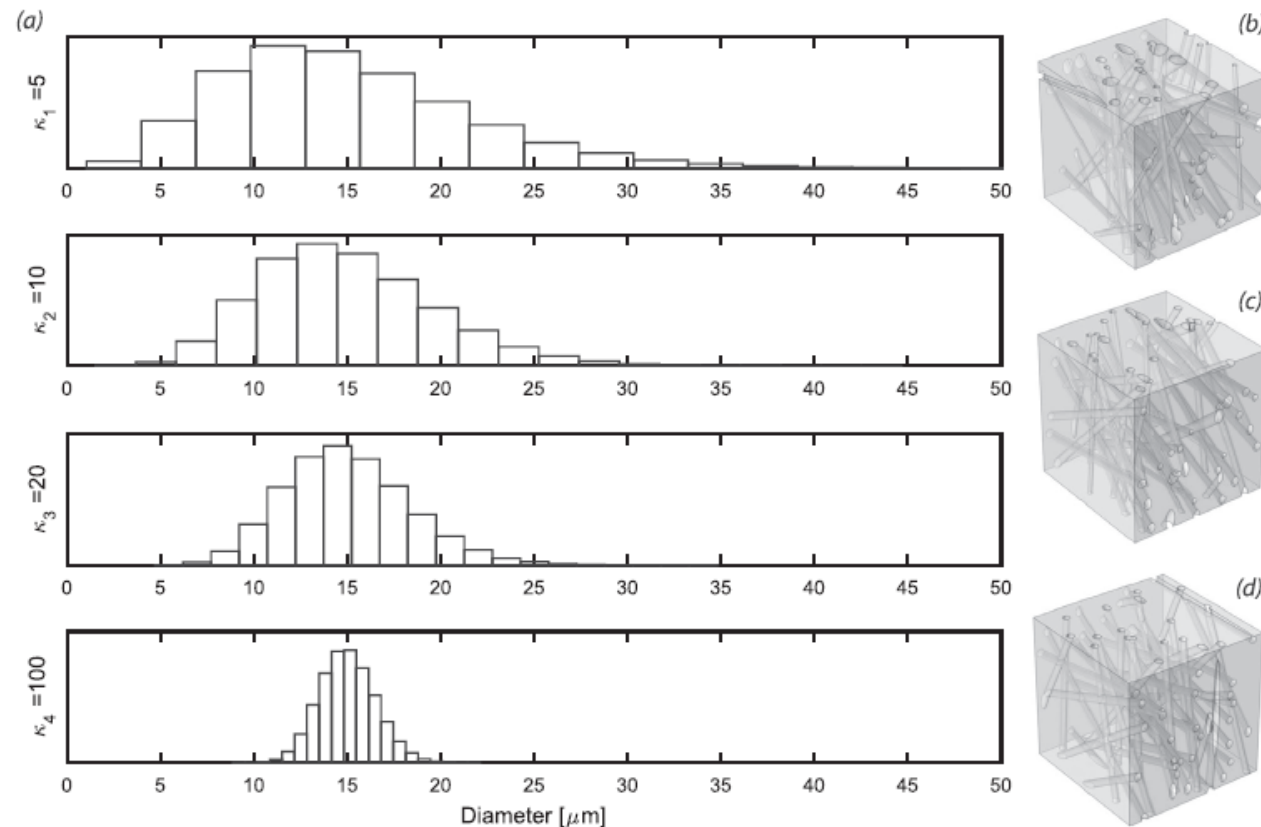
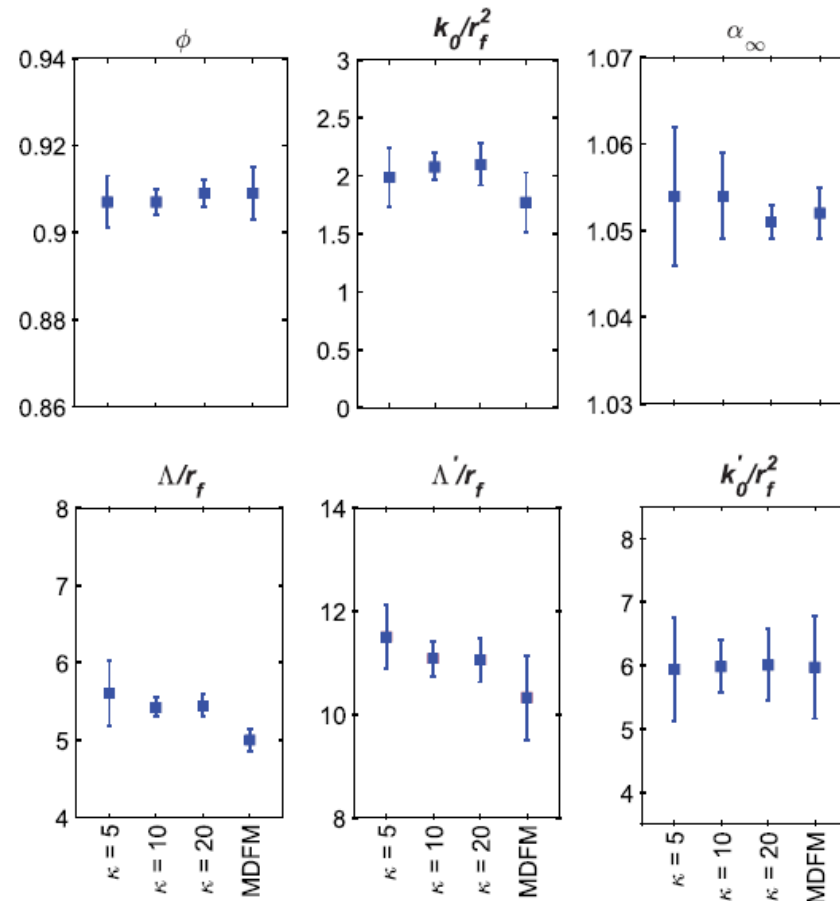


Fig. 1. (a) The evolution of Gamma distribution on the variation of shape parameter κ . The mode of the distribution is given by $(\kappa-1)\theta = 15 \mu\text{m}$. Different REV configurations corresponding to various shape parameters: (b) $\kappa_1 = 5$, (c) $\kappa_2 = 10$, (d) $\kappa_3 = 20$.

Substituting a polydisperse distribution of the fiber diameters by an equivalent monodisperse one?

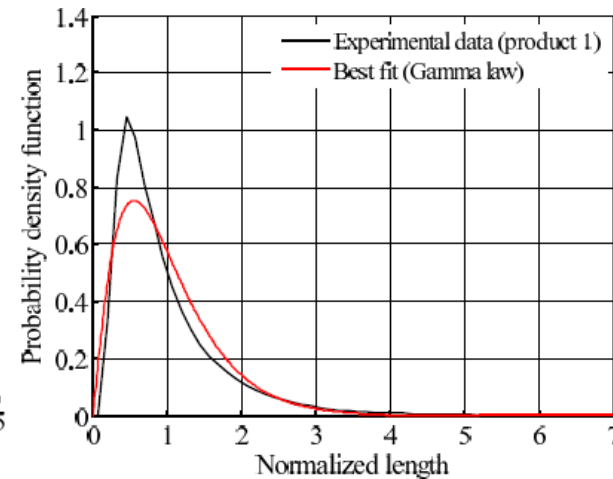
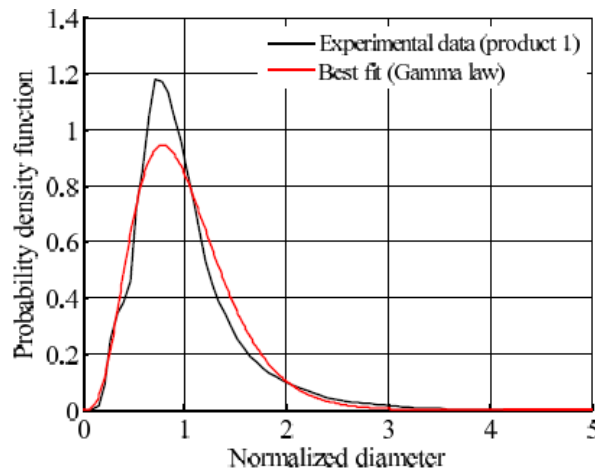
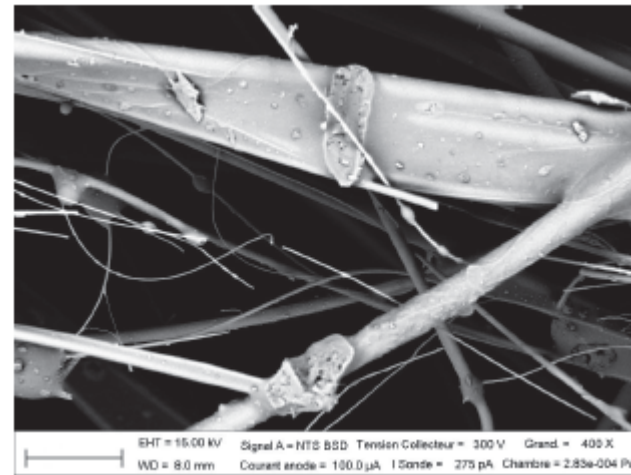
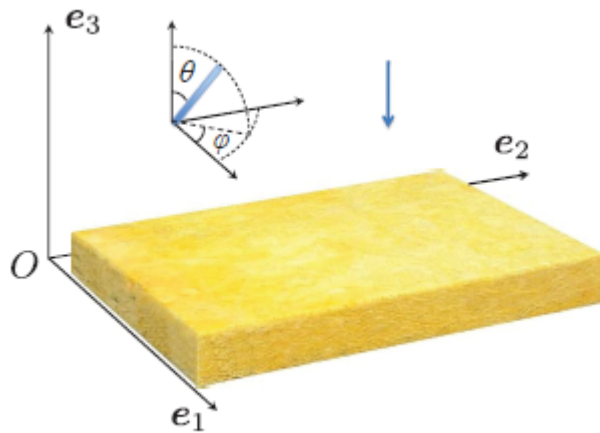
A) Polydisperse fiber distribution (PDFD)



[H. T. Luu, R. Panneton, C. Perrot, "Effective fiber diameter for modeling the acoustic properties of polydisperse fiber networks" J. Acoust. Soc. Am. 141, EL 96 (2017)]

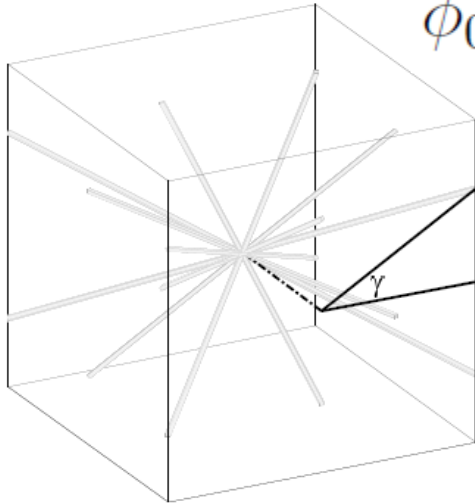
Handling for complex fibrous media presenting both a wide distribution of fiber diameters and fiber lengths

A) Motivation



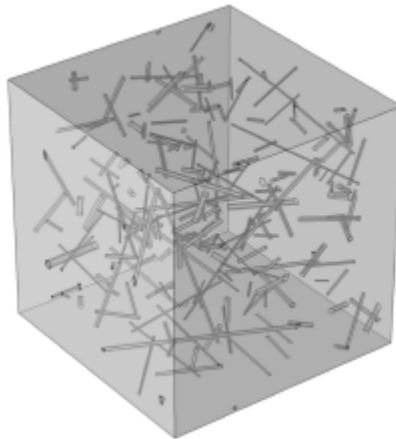
Geometrical models: Deterministic and fully stochastic

$$\phi_0(D_w/L, \gamma^{exp}) = \phi_0(D_0/L_0, \gamma^{exp}) = \phi^{exp}$$

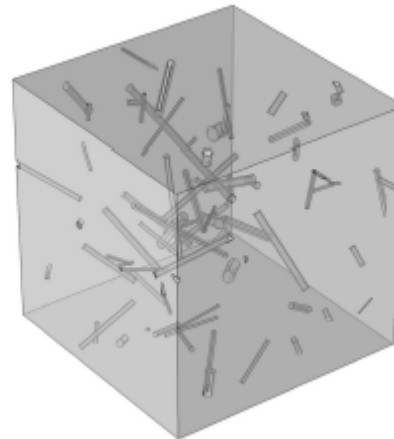


$$D_w = \frac{1}{\sum_{i=1}^{N_f} V_i} \sum_{i=1}^{N_f} V_i D_i$$

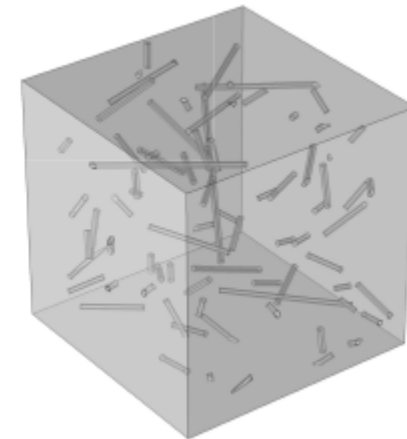
Model 1



Model 2



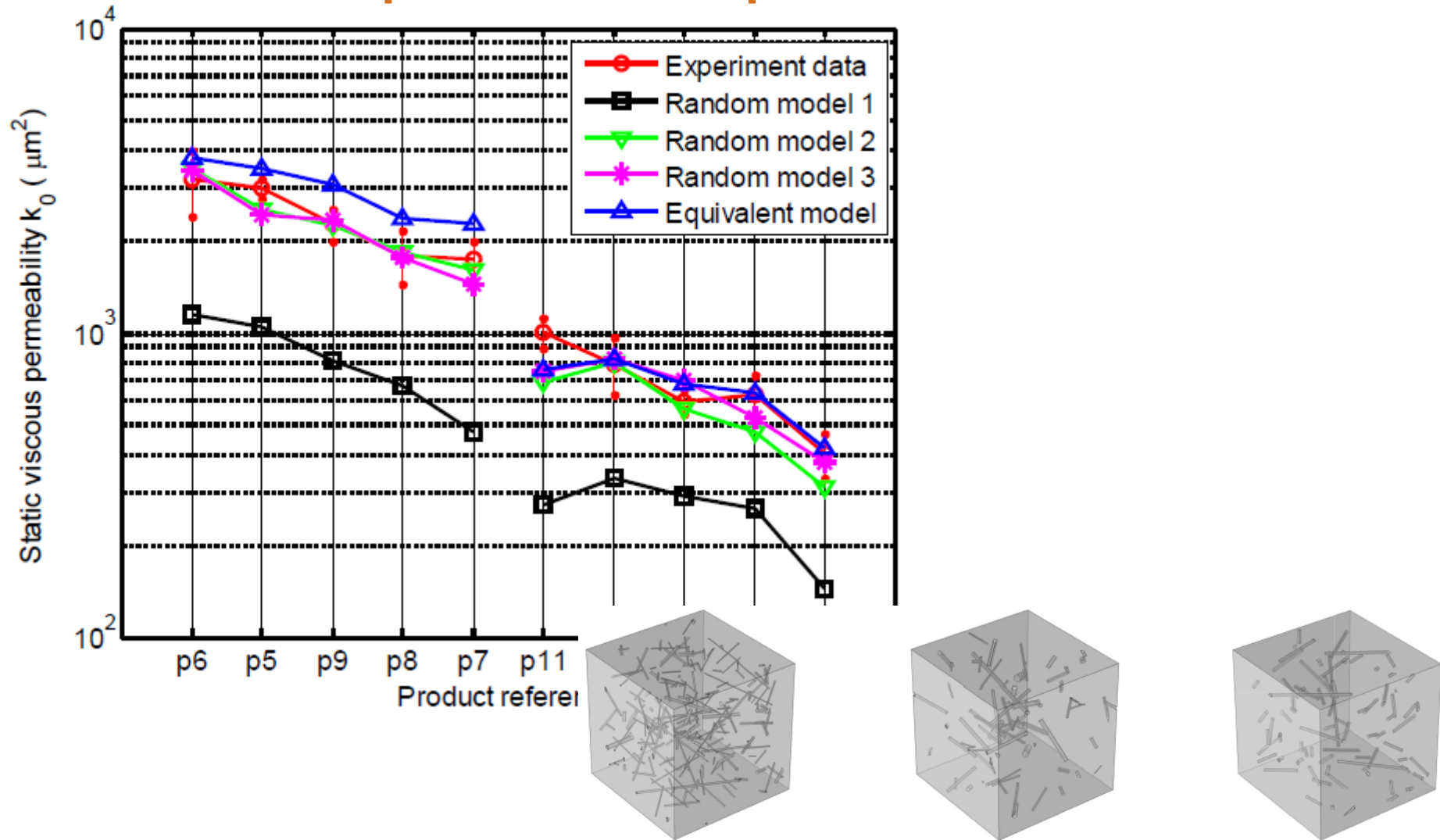
Model 3



Volume weighting averaging

Volume weighting averaging—
 Mean value

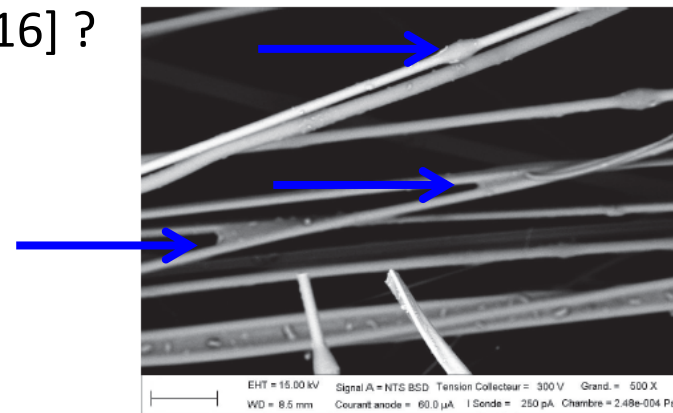
Comparison with experimental results



M. He, C. Perrot, J. Guilleminot, P. Leroy, G. Jacques "Multiscale prediction of acoustic properties for glass wools: Computational study and experimental validation" Under review in the J. Acoust. Soc. Am.

Conclusion and future works

- Stochastic geometry and numerical homogenization used to describe transport and sound absorbing properties fibrous materials without fitting.
- Correlations have been derived to account for geometrical effects on transport parameters
- Monodisperse fibrous media can be used as an equivalent fibrous media to describe polydisperse and bidisperse fibrous media (in diameter).
- Role of volume weighting in the accurate prediction of complex fibrous media (wide distribution)
- Role of fibers curvature and links (binder) in the prediction of elastic properties sound insulation) [PhD Thesis L. Chappelle, 2016] ?



Acknowledgments

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- Agency for Environment and Energy Management (ADEME), The Scientific and Technical Centre for Construction (CSTB) and ISOVER: PhD Thesis M. He.

Thank you for your attention !