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Identification of microstructural descriptors characterizing the macro-behavior of polydisperse random fibrous media

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Fine predictions of the transport and acoustical properties of composite felts can now be obtained in principle using sophisticated fiber scale numerical approaches. However, there is still a need, in particular for polydisperse random fibrous media, to identify the appropriate microstructural descriptors of the models that enable an accurate prediction of the transport coefficients of these nonwovens from the knowledge of various distributions about their fiber orientations and fiber diameters. For that purpose, polydisperse composite felts were manufactured with transversely isotropic random fibrous structures, and oriented fibrous microstructures corresponding to different compression rates before thermobonding. The fibrous microstructures of these composite felts were characterized using scanning electron microscope images taken on orthogonal sections of the studied specimens. The corresponding images revealed a wide distribution of fiber diameters and a standard deviation of the azimuthal angle of fibers decreasing with increasing compression rate. Furthermore, the evolution of their transport properties with compression rate, when normalized by the average fiber diameter as microstructural descriptor, were not captured by the current models or required prior knowledge of all the transport properties from measurements in the initial state. In light of these experimental data, we developed a fiber network model for the through-plane transport processes of transversely isotropic random fibrous media in which the main visco-thermal dissipation mechanisms of the polydisperse fibrous structure are related to the largest channels within the fluid phase, whereas the smallest channels were considered as leading the inertial behaviors. The viscous and thermal permeabilities of composite felts were then estimated numerically from a representative elementary volume (REV) with a volume weighted average diameter, and the viscous and thermal characteristic lengths from a REV with inverse volume weighted average diameter (Figure 1). A unified empirical model was proposed. The model predictions agree with the experimental results, without adjusting any microstructural parameter.

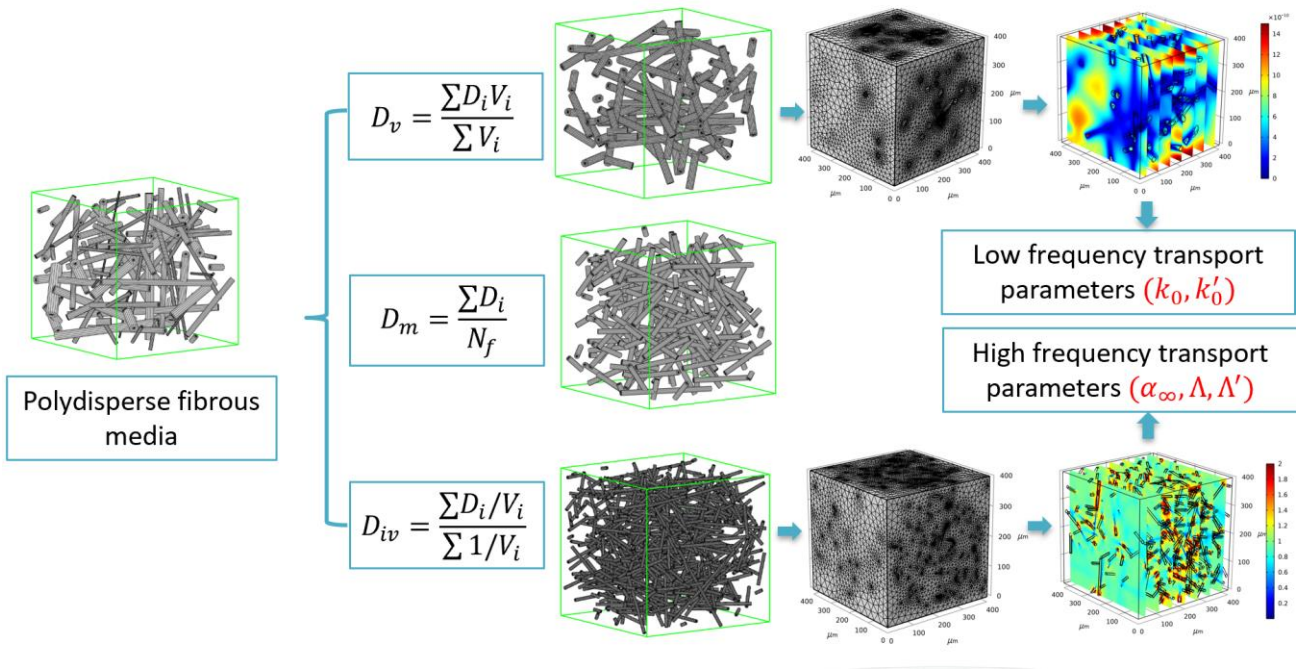


Figure 1: Illustration of the proposed methodology used to identify the microstructural descriptors D_v and D_{iv} enabling to predict the transport and sound absorbing properties of a polydisperse random fibrous media. Note that D_v is the volume weighted average diameter, D_{iv} is the inverse volume weighted average diameter, whereas D_m is the average diameter; V_i is the volume of the i^{th} fiber and N_f corresponds to the number of fibers.