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A JOINT MODELLING APPROACH FOR THE ACOUSTIC AND THERMAL PROPERTIES OF FIBROUS MATERIALS: APPLICATION TO BUILDING'S VEGETAL WOOLS

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ABSTRACT

In order to jointly predict the acoustic and thermal properties of fibrous materials, a joint modelling approach relating their microstructural parameters to their macroscopic properties is developed. This original approach can be applied for vegetal wools increasingly used in green buildings field.

1. EXTENDED ABSTRACT

Biobased fibrous insulation materials, such as vegetal wools, that belong to the green carbon sector, more specifically in green building fields, provide an effective response in a sustainable way. Indeed, they are able to store atmospheric carbon dioxide [1] and contribute to limiting the impact on biodiversity. Moreover, they have a number of multifunctional properties [2].

This potential is represented more particularly by acoustic and thermal high level performances due to their specific microstructure [3, 4].

In this context, an innovative acoustic and thermal joint modelling approach has been developed as shown in Figure 1.

This approach is based on a micro-macro homogenisation method. Only two input parameters are necessary to obtain fibrous material properties: the fibrous material open porosity ϕ and an equivalent fibre radius value Rf_{eq} .

For the acoustic and the thermal conduction transfer modelling, the macroscopic behaviour laws are established by using the homogenisation of periodic media (HPM) [5].

However, HPM is used regardless of the chosen periodic representative elementary volume (PREV). Therefore, numerical computations must be carried out to solve the equations and to obtain solutions. So, in order to find analytical solutions, it is possible to use a Self-Consistent Method (SCM) based on a simplification of the PREV [6]. In the fibrous material case based on a cylindrical geom-

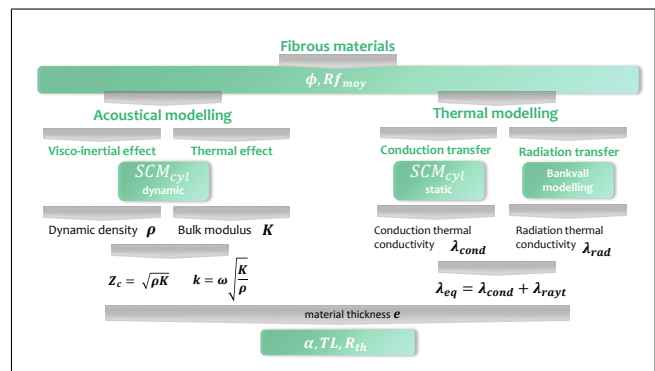


Figure 1. The joint acoustic and thermal modelling approach for fibrous materials

etry representative of the fibres morphology, it is called SCM_{cyl} .

To do this, at microscopic scale, we considered a generic cylindrical inclusion described by a cylinder of radius (R) and surface (∂R) as shown in Figure 2. The solid phase is represented by a fibre of volume (Ω_s) and a radius (βR). This radius is considered constant along its entire length and, in first approximation, large in comparison with the cylinder cross-section. This solid phase is included in the fluid phase represented by an air cylinder hollowed out in its center, with an external radius R and an internal radius βR .

Moreover, the SCM is based on the energy equivalence between the cylindrical generic inclusion, representative of the fibrous material physical and geometrical properties at microscopic scale, and the equivalent homogeneous medium at the macroscopic scale.

For the acoustic properties modelling, SCM_{cyl} is developed in a dynamic approach (function of frequency) [7]. As shown in the Figure 1, it leads to the determination of both parameters, the dynamic densities ρ and the bulk modulus K . Then, it is possible to obtain the intrinsic pa-

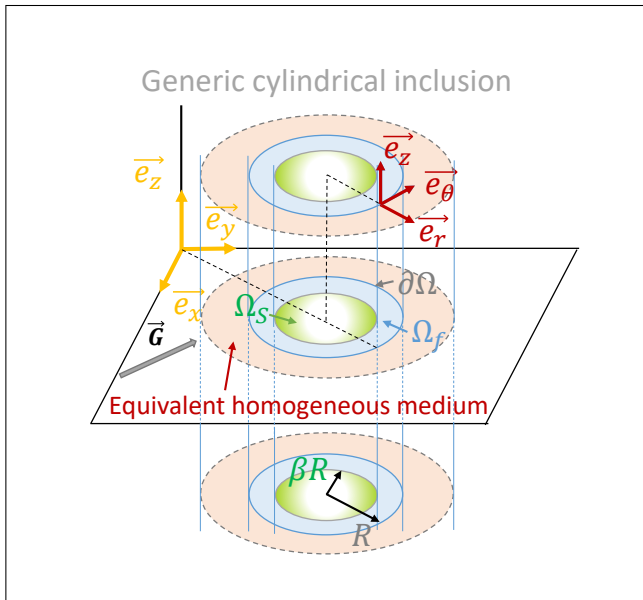


Figure 2. Schematic representation of a fibrous medium at macroscopic and microscopic scales by the periodic cell Ω . Ω_s and Ω_f correspond to volumes of the solid and fluid phases. Γ is the solid-fluid interface.

rameters of the materials, i.e. the characteristic impedance Z_c and the wave number k .

For the thermal properties modelling heat transfer contributions are represented by a specific thermal conductivity: λ_{cond} for conduction and λ_{rad} for radiation. SCM_{cyl} is developed in a static approach for the conduction transfer modelling [4]. In order to take the significant impact of radiation transfer for materials with densities below 30 kg.m^{-3} into account, the Bankvall empirical modelling approach is used [8]. It is also based on the both parameters ϕ and Rf_{eq} .

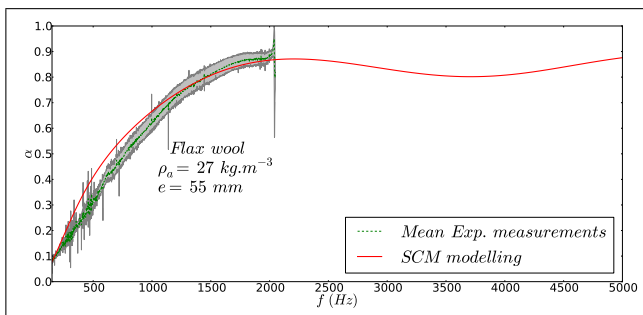


Figure 3. SCM_{cyl} modelling of acoustic absorption coefficient for a flax wool

Finally, validation of this acoustic and thermal joint modelling approach is carried out by comparing results with vegetal wools experimental data, as shown in Figures 3 and 4 for a flax wool.

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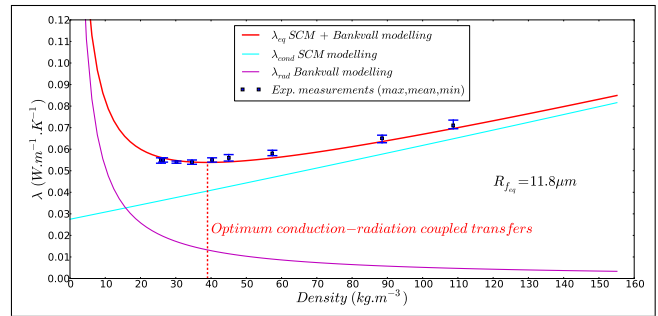


Figure 4. Modelling of thermal conductivity for a flax wool

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