

Micro-scale finite element simulation of the viscoelastic damping in unidirectional fiber reinforced composites

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Fiber reinforced composite materials are rapidly emerging in the different industries such as automotive, marine and civil engineering. Therefore profound characterization of the mechanical behavior of this family of materials is highly important. Although the static behavior of fiber reinforced composites has been researched extensively, their dynamic, specifically damping, behavior has not been widely studied.

Damping behavior of a fiber reinforced composite is induced by different sources such as viscoelastic damping of constituents, interface damping and thermo-elastic damping. In fact, damping of fiber reinforced composites can be considerably higher than that of the traditional metallic materials, and this capacity provides them a high potential to be used in the dynamic applications. Among the abovementioned damping sources, viscoelastic behavior of constituents (polymer matrix and fibers) plays a major role.

This article studies contribution of the viscoelastic damping of each constituent in the anisotropic damping behavior of a unidirectional fiber reinforced composite in the micro-scale. To this purpose, fiber and polymer matrix are modeled as viscoelastic materials and the boundary problem is solved for a cyclic dynamic loading, using the finite element approach. Thereby the different loss factors of a composite are homogenized and computed using the hysteresis stress-strain analysis.

The previous relevant studies consider unit cells with a single fiber or basic fiber packing with simplified boundary conditions, and most of those studies do not homogenize the damping properties. In this work, the simulations have been performed on a periodic Representative Volume Element (RVE) composed of randomly distributed fibers in polymer matrix including Periodic Boundary Conditions (PBC). The simulations have been performed on a two-phase material composed of glass fibers and an epoxy resin, and it is presumed that the bonding between the fiber and the matrix is perfect. The materials are simulated through a user subroutine applying Kelvin-Voigt viscoelastic model. The simulation results are also compared to the strain energy method in which the loss factors of a composite are expressed as the ratio of summation of the product of the strain energy stored in an individual element and the element's loss factor to the total strain energy. Furthermore, two different parametric studies are performed. Firstly effect of the loading frequency on the homogenized loss factors of the composite is evaluated and afterwards effects of the fiber volume fraction and fiber size are studied.