Electromagnetic properties of fiber-reinforced laminates

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***Abstract*—The optical and electromagnetic properties of fiber-reinforced glass-epoxy composite material are reported in this article. Circular fibers are periodically embedded into a slab of epoxy material as reinforcements. Several fiber-reinforced slabs are overlapped with fibers orientated arbitrarily from one to another with full generality. The optical and electromagnetic properties of this fiber-reinforced material as used in space vehicles or other industries is studied by combining Rayleigh's method and mode-matching method. Wave propagation in the material is described with scattering matrices and reflection/ transmission coefficients. Strong absorption is observed with carbon-fiber-reinforced glass-epoxy structure, but full reflection or transmission show up in this kind of composites.**

Keywords—Rayleigh's method, Mode-matching method, fiber-reinforced composite

Fiber-reinforced composite materials could be widely used in the fields from electrical devices to space vehicles and civil industries [1][2][3]. Those constructed by regularly arranging reinforcements can provide more control on the optical and electromagnetic properties of the composites. The knowledge on the electromagnetic behaviors of these structures are important in some of these applications [4], and it is also important for non-destructive testing of modern composite materials [1][5]. In this paper, the electromagnetic properties of fiber-reinforced composite are studied based on Rayleigh's method and mode-matching method.

Ideally, taking a planar slab reinforced by a periodic array of cylindrical fibers orientated into the same direction as a building block, a laminated structure follows by piling up the slabs, the fibers in each slab orientating into different directions if/as needed. This arrangement provides best mechanical strength and stiffness in all directions. However, it brings difficulties to investigate its electromagnetic properties with numerical methods based on the periodic surface integral formulation [6], on FDTD [7], or on FEM [8] because there is no good way to applying periodic boundary conditions to satisfy simultaneously all the periodicity of different layers. The analytic equivalent-layer method [9] has shown good potential in a low-frequency range, but it is hard to be extended for investigations in optical frequency range. As for the peculiar case of woodpiles [10][11]. The emphasis is on Rayleigh's method [12] and plane wave expansions for ensuring both computational efficiency and accuracy as well as analytic tractability [13]. All such approaches so far appear limited to layers with a single direction of periodicity, or to the aforementioned woodpiles [14]. For more complicated cases with arbitrarily different orientations of cylinders from one layer to the next, they might not be well-suited.

The present investigation aims at investigating the electromagnetic properties of the composites based on the method proposed by the authors [15][16]. A pile made of three layers with different orientations of cylinders is considered. The electromagnetic properties are mostly influenced by the periodicity of each layer and the size of the fibers as well as the height of the epoxy slabs. One can adjust these parameters to make the structure to have total reflection or transmission properties in a wide frequency band. When carbon fibers are included into the structure, good absorption of the waves can be observed. All these electromagnetic properties can be used for antenna Radom, electromagnetic wave shielding or RCS reduction of antennas etc. Detailed theoretical and numerical investigation will be presented in the conference with a full discussion of the electromagnetic properties of fiber-reinforced laminates.

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