博 士 論 文 の 内 容 の 要 旨

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論文題目	Electromagnetic interference shielding anisotropy of CFRP composites and its applications （CFRP 複合材料の電磁波遮蔽異方性とその応用に関する研究）

（博士論文の内容の要旨）

Recently, carbon fiber reinforced polymers (CFRP) composites has attracted great attention in many industrial fields to resolve electromagnetic pollution due to their electromagnetic interference (EMI) shielding performance. CFRP composites have anisotropic properties, including anisotropy of electrical conductivity and dielectric characteristics. These features lead to EMI shielding anisotropy of the CFRP. Besides, when CFRP is damaged internally, its shielding performance will be significantly affected, making it possible to use EM microwave technology for non-destructive testing (NDT) of CFRP. This study is mainly focus on investigating EMI shielding anisotropy and shielding mechanisms of CFRP composites. Theoretical formulas were used to analyze and predicted the electrical conductivity and EMI shielding performance of CFRP composites. The optimization of EMI shielding performance with CFRP laminated structures was also investigated. Moreover, a new type of nondestructive testing (NDT) method using electromagnetic wave (EMW) technique was proposed. The significant results obtained from this research are as follows:

(1) EMI shielding anisotropy was confirmed for the first time by the coaxial transmission line method. A quasi-radial sample had the highest shielding effectiveness (25.8 dB) at 15 GHz, and the carbon fibers in this sample aligned in the direction of the electric field of EM waves. A CFRP composite with fibers in a parallel (0°/0°) arrangement had the lowest SE (15.9 dB) at the same frequency. Hence, the orientation of fibers relative to the direction of electric field clearly affected the EMI shielding performance of the CFRP composites. The four-ply CFRP (0°/90°/0°/90°) with three cross-layers had the highest shielding value of 28.9 dB at 15 GHz, that was far superior to that of a unidirectional CFRP (0°/0°/0°/0°) composite (SE= 18.6 dB), and it even outperformed an eight-ply unidirectional CFRP composite (SE= 22.6 dB). Laminated structures governed SE, and the number of cross-layers in the composites improved their EMI shielding performance. We believe that these findings could provide a scientific basis and potential in designing high-performance EMI shielding materials.

(2) The electrical conductivity of unidirectional CFRP composites was identified to vary with the fiber orientation angles, and the formula was proposed to predict the results consistent with the experimental. The obvious EMI shielding anisotropy of unidirectional CFRP composites was clarified by free-space measurement. The theoretical formula can predict the EMI shielding value at different carbon fiber

orientation angles, and the predicted results were highly consistent with the experimental results. A comparison of free-space measurement and coaxial transmission line method was also conducted, which indicated that special attention should be paid to the influence of the anisotropy of CFRP composites on the shielding results. With those results, the mechanism of EMI shielding anisotropy of CFRP composites is clarified, which will provide an effective design of EMI shielding products with a designable shielding direction and frequency.

(3) The proposed EMW-NDT method is effective in detecting damages such as delamination, crack or other defects in CFRP composites. The results confirmed that the proposed method demonstrates good detection sensitivity to delamination size and thickness. Besides, the slit and its length were detected and the slit direction was successfully identified in this study. The proposed EMW-NDT method with specified designed free-space measurement system is contactless, and coupling medium is not required; thus, it exhibits huge potential to be widely used as a new damage detection technique for CFRP composites.