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博　士　論　文　の　要　旨

専攻名　　システム創成科学専攻

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学位論文題名

Subsurface damage detection in CFRP using dynamic shear strain analysis of Lamb wave
（ラム波の動的せん断ひずみ解析を用いた CFRP 中の表面下損傷の検出）

要旨

Carbon Fibre Reinforced Polymer (CFRP) is a reliable and light fibre-reinforced plastic which contains carbon fibre, nowadays are extensively used wherever high strength-to-weight ratio and rigidity are required, such as aerospace, automotive, structures, sports goods and technical applications. The material properties of such kind of composites depend on the strength-providing part, carbon fibre, and the bonder of the reinforcements together, a polymer resin. Composites offer the designer a combination of properties not available in traditional materials. As with all materials that are used to make objects and structures, there is a need to be able to inspect the equipment to determine its fitness for purpose or use. Inspection of composite material poses a particular challenge since the materials are often non-homogeneous and anisotropic. Flaws can occur in composites at any stage of the lifecycle, i.e., during production or in-service, most likely in fiber distribution or the matrix. Typical examples of flaws found in composites are delamination, cracks, disbonds, impact, fiber breakage, voids, etc.

The integrity and degradation of composite structures have been traditionally evaluated by nondestructive testing (NDT) or by nondestructive evaluation (NDE), now being potentially assessed by structural health monitoring (SHM), to assure the performances of these structures. The detection of flaws is vital in ensuring the safety and timely repair of structures. In comparison with conventional NDE techniques such as ultrasonic scanning and radiography which have been well developed over half a century, damage identification using Lamb waves is in a stage of burgeoning development. Lamb waves are guided waves having dispersive behaviors that propagate in the thin plate or shell structures. The use of Lamb wave in SHM is attractive for the last couple of decades since a large area of structure can be interrogated from only a few locations. The detection of damages comes from the interaction of Lamb waves with disturbances in the compositions.

In 2011, Prof. Teramoto has proposed a novel NDE technique named by dynamic shear strain analysis. In this research, the effectiveness of dynamic shear strain analysis is assessed to detect the subsurface damage in the composite laminates. The technique focusing on the near-field imaging method over the fundamental mode of anti-symmetric Lamb wave field. The incoming wave field strikes at the boundary of the flaw generates evanescent wave field which diminishes exponentially. The orthogonal pair of out-of-surface shear strains follows linearity condition in the flawless region. In contrast, at the boundary of the defect, the requirement violates as the scattered wave field does not follow the path of incident one. A covariance matrix consisting the vector of shear strain has been adopted in such way that the determinant of the matrix exhibits any value other than zero at the region of violation. As a whole, the image of the defect is reconstructed. This thesis makes explicit the applicability of the dynamic shear strain analysis to orthotropic material in the context of unidirectional, bi-directional, and quasi-isotropic composite laminates by means of numerical experiments. All of the experimental results showed excellent

agreement with the mentioned novel NDE technique.