Avis de Soutenance

Shuanglin GUO soutiendra ses travaux de thèse intitulés **« Contribution to the study of guided waves propagation and attenuation in anisotropic composite laminates made up of viscoelastic composite materials : Application to A380 mounted nacelle parts"**

Soutenance prévue le **le Jeudi 9 Décembre 2021 à 9h30**
Arts et Métiers - Campus de Paris - HESAM Université, 151 Boulevard de l'Hôpital, 75013 Paris
Salle : Amphithéâtre FOURNEL

devant un jury composé de :

- Mme Zahra SHARIF KHODAEI, Associate Professor, Imperial College, London : Rapporteur
- Mr Kerem EGE, Maitre de conférences (HDR), INSA Lyon : Rapporteur
- Mr Alain LHEMERY, Directeur de Recherche, CEA : Examinateur
- Mr Zhenghua QIAN Professor, Nanjing University of Aeronautics & Astronautics : Examinateur
- Mr Marc REBILLAT, Maitre de Conférences, ENSAM : Examinateur
- Mr Nazih MECHBAL Professeur, ENSAM : Examinateur

Abstract : *Anisotropic composite plates made up of viscoelastic composite materials are increasingly used in aeronautic industry and structural health monitoring (SHM) strategies based on guided waves appear as a very promising tool to monitor their health state. In that context, this thesis is dedicated to the study of guided waves propagation and attenuation in such composite plates. The fundamental equations of three-dimensional (3D) elasticity theory are first reviewed. Various composite materials are introduced with an emphasis on their characteristics of stiffness matrix rotation. The partial wave superposition approach (PWSA) based on 3D elasticity is used to derive the dispersion equations of guided waves propagating in a single layer composite lamina. In a multi-layered composite plate system, the PWSA is extended to the transfer matrix method (TMM) which connects the neighboring layers' field variables (displacement and stress) through the local lamina matrices. For an arbitrarily oriented composite laminate, the matrix incompatibility issue of TMM is encountered due to the anisotropy of composite materials, and an original hybrid matrix strategy (HMS) is proposed to address this issue that recasts the incompatible layers' local lamina matrices into a hybrid form to guarantee the successful proceeding of the transferring process of TMM. The HMS is validated in a quasi-isotropic plate and a metallic-composite plate. To improve the computational efficiency of the global matrix method (GMM), an optimized GMM is developed that introduces the symmetry condition into the global matrix to reduce matrix order and takes advantage of sparse matrix and parallel computing techniques to promote computing performance. The optimized GMM is applied to an aerospace composite plate having 400 layers, which is the largest number of layers reported so far, for computing its phase velocity dispersion curves. Due to the complexity of this structure, the dispersion diagram experiences heavy veering effect which is the phenomenon of dispersion curves belong to the same symmetry mutually closing but never crossing in a small region. Mode shape analysis and MAC value tomography are used to analyze veering effect. Results reveal that the closing modal curves exchange their mode shapes rapidly in* *these regions. It is furthermore demonstrated that dispersion equations built with PWSA for a single layer plate and with TMM and GMM for a multi-layered plate system possess a dichotomy property in the case of pure elastic materials. This property states that these a priori complex-valued equations collapse to pure real or imaginary valued equations, depending on the behavior of some intermediate parameters. This is extremely helpful for overcoming numerical instabilities encountered during the equation solving process. With the dichotomy property, the large fd problem of TMM results from the vanishing of effective part between the real and imaginary parts of dispersion equations due to the poor conditioning of the monodromy transfer matrix. Composite materials possess inherent viscoelasticity which produces guided wave amplitudes attenuating with propagation distance. To predict attenuation coefficients of anisotropic composite laminates, three damping models (Hysteretic, Kelvin-Voigt and Biot models) are integrated into GMM to form the damped GMM framework (dGMM). Attenuation coefficient is computed from the solutions of complex dispersion equations built with dGMM. Two aeronautic components of A380 plane both which are either mounted or unmounted on the plane are employed to validate the developed dGMM. The first one is a fan cowl structure having quasi-isotropic property and the second one an inner fixed structure being a sandwich plate. Theoretical and experimental analysis reveal that the attenuation coefficients of both structures hold anisotropic property in terms of spatial distribution despite the quasi-isotropic stacking layups of them. The existence of stress in the mounted case can greatly change the property of attenuation as compared to the unmounted case. In both structures, A0 mode undergoes much attenuation than S0 mode, which gives the guidance that selecting S0 mode for SHM of similar aeronautic structures is more desired in the selected frequency range. The works conducted in the thesis provides inspirations for optimally deploying sensor networks by considering the influence of wave attenuation and for improving damage localization methods that takes advantage of frequency-wavenumber analysis.*