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Review report on the PhD thesis "Dynamic modeling of Macro-Fiber Composite transducers integrated into composite structures" submitted by ZhongZhe Dong

Dear Madam / Sir,

The main scope of Mr ZhongZhe Dong's thesis is the investigation of the effective modeling of Macro-Fiber Composite (MFC) transducers integrated into composite plates, which could allow the proper assessment of their performance. Composite structures are widely used in engineering applications and the introduction of isotropic or anisotropic layers provide various options for the design of lightweight structural components, optimizing their mechanical characteristics. However lightweight structures can be susceptible to external disturbances due to their low mass and damping. As a result unwanted noise and vibration may occur. Trying to reduce these effects, smart structures have been proposed, integrating actuators and sensors in the main structures. Macro Fiber Composite (MFC) piezoelectric transducers appear as an attractive solution due to their high flexibility, their high reliability and their high performance. On the other hand the influence of their positions and orientation on the mechanical properties of the global structure is not yet clear.

Mr Dong in the frames of his dissertation contacted research on the laminated composite plates with spatially distributed rectangular MFC transducers. The spatial distributions that describe the position of the transducers have been introduced into a generalized Hamilton's principle approach aiming to the estimation of the equivalent loads of the MFC transducers. The development of equivalent forces is proposed in order to characterize the inverse piezoelectric effect of the integrated MFC transducers, calculating in parallel the corresponding direct piezoelectric effect through the electrical boundary conditions of the system. Two Finite Element Method (FEM) – based semi-analytical modeling approaches, the Equivalent Force Modelling (EFM) and the Equivalent Substructure Modelling (ESM), have been introduced. The first one allows the individual modelling of the mechanical and piezoelectric aspects of piezoelectric composite plates, using closed-form piezoelectric couplings. The Equivalent Substructure Modelling (ESM) approach is based on the first one and has been developed in order to generate system models of piezoelectric composite structures which are a) stable, b) structure-preserving and c) of low-order. Those models are further used in order to evaluate the position and the piezoelectric fiber orientation of the MFC transducers, focusing towards the maximization of their performance. The ESM approach presents also the stability of the original system models allowing the design of advanced controllers in a Noise Vibration and Harshness (NVH) concept. The developed methodologies have been tested and evaluated first on different numerical simulations and then on realistic test cases. A laminated composite plate has been manufactured and the ESM approach has

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been evaluated on an energy harvesting concept as well as on a damping concept. Furthermore in order to investigate the reversibility of the piezoelectric effect and demonstrate the dynamic properties of a piezoelectric transducer in a vibro-acoustic field, the general methodology was evaluated on a dedicated test rig, the KU Leuven sound box. The global contributions of the thesis can be summarized as: a) characterization of non-homogenous laminated composite plates with integrated MFC transducers, b) development of an equivalent dynamic modeling approach, c) experimental validation of the methodology and d) vibro-acoustic study of MFC transducers integrated into composite plates.

During his thesis, ZhongZhe Dong published two peer-reviewed journal papers, one peer-reviewed conference paper and six conference papers.

Based on the manuscript prepared by ZhongZhe Dong and the papers he has already published, I assessed the PhD and I hereby would like to confirm the high quality of the implemented research and the contribution to the state of the art. I would like to further mention that Mr ZhongZhe Dong proved his ability to perform independent and collaborative research and to effectively achieve results, developing theory and validating it with experiments. Therefore I would like to recommend the thesis for admission for a doctoral defense.

Kind regards

Konstantinos Gryllias [redacted] lieke

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