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Experimental-Numerical Inverse Approaches in the Characterization and Damage Detection of Soft Viscoelastic Layers from Vibration Test Data

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Abstract : Viscoelastic materials have been widely used in the automotive industry over the last few decades with different functionalities. Besides their main application as a simple and efficient surface damping treatment, they may ensure optimal operating conditions for on-board electronics as thermal interface or sealing layers. The dynamic behavior of viscoelastic materials is generally dependent on many environmental factors, the most important being temperature and strain rate or frequency. Prior to the reliability analysis of systems including viscoelastic layers, it is, therefore, crucial to accurately predict the dynamic and lifetime behavior of these materials. This includes the identification of the dynamic material parameters under critical temperature and frequency conditions along with a precise damage localization and identification methodology. The goal of this work is twofold. The first part aims at applying an inverse viscoelastic material-characterization approach for a wide frequency range and under different temperature conditions. For this sake, dynamic measurements are carried on a single lap joint specimen using an electrodynamic shaker and an environmental chamber. The specimen consists of aluminum beams assembled to adapter plates through a viscoelastic adhesive layer. The experimental setup is reproduced in finite element (FE) simulations, and frequency response functions (FRF) are calculated. The parameters of both the generalized Maxwell model and the fractional derivatives model are identified through an optimization algorithm minimizing the difference between the simulated and the measured FRFs. The second goal of the current work is to guarantee an on-line detection of the damage, i.e., delamination in the viscoelastic bonding of the described specimen during frequency monitored end-of-life testing. For this purpose, an inverse technique, which determines the damage location and size based on the modal frequency shift and on the change of the mode shapes, is presented. This includes a preliminary FE model-based study correlating the delamination location and size to the change in the modal parameters and a subsequent experimental validation achieved through dynamic measurements of specimen with different, pre-generated crack scenarios and comparing it to the virgin specimen. The main advantage of the inverse characterization approach presented in the first part resides in the ability of adequately identifying the material damping and stiffness behavior of soft viscoelastic materials over a wide frequency range and under critical temperature conditions. Classic forward characterization techniques such as dynamic mechanical analysis are usually linked to limitations under critical temperature and frequency conditions due to the material behavior of soft viscoelastic materials. Furthermore, the inverse damage detection described in the second part guarantees an accurate prediction of not only the damage size but also its location using a simple test setup and outlines; therefore, the significance of inverse numerical-experimental approaches in predicting the dynamic behavior of soft bonding layers applied in automotive electronics.

Keywords : damage detection, dynamic characterization, inverse approaches, vibration testing, viscoelastic layers
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