Optimization of the design parameters of a Phased Array based Ultrasonic Polar Scan system

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Various industries are pushing the use of composites as these materials provide interesting benefits such as for instance a high stiffness-to-weight ratio. On the down side, these types of materials are generally very challenging to characterize due to their anisotropic nature. To overcome this problem, we propose to use the Ultrasonic Polar Scan (UPS), a relatively new (Non-Destructive Testing) NDT technique that can be employed to determine the full viscoelastic C-tensor in a single measurement procedure. In this technique, a single material spot is insonified by a broadband ultrasonic signal from multiple angles of incidence $\Psi(\theta,\phi)$, after which the reflected or transmitted signals are recorded. Based on these data, the reflection or transmission coefficients, and Time-Of-Flight (TOF) can be deduced, which in turn can be exploited to determine the viscoelastic properties of the material through an inversion procedure. Even though a standard and fully automated experimental setup is at hand, and is able to generate data of excellent quality, it is too large to be efficiently used in an industrial setting. Therefore, we propose to downscale the system by using a combination of cylindrically focused emitters and a phased array receiver. Doing so, less motorized movements are needed, and the receiver aperture is greatly increased. In fact, only the incident polar ϕ angle has to be controlled using a motorized rotation around the normal to the plate, while approximate plane wave reflection coefficients for a specific incident angle θ can be determined using dedicated post-processing techniques. As part of this new development, a 3D simulation model is proposed based on analytical techniques to treat the incident beam-plate interaction and the propagation of the reflected field towards the array elements. The model allows to simulate a complete UPS experiment of the phased array system, and validates that approximate plane wave results can indeed be achieved through proper post-processing of the data, provided suitable design parameters are used. To help identifying the best design of the system, a parameter study is conducted in which the radius of the device, the phased array dimensions, the number of emitters, etc. , are varied. A first impression of the quality of the data is obtained by evaluating the Root Mean Squared Error (RMSE) of the result with respect to the expected plane wave data. Next, as even slight differences with respect to the plane wave result might impact the quality of the inversion of the C-tensor, we studied the sensitivity of the inversions on the simulated UPS data and analyzed the induced error on the C-tensor. These results are finally used as a means to determine the optimal design parameters of the setup.