Identification of the Adhesive-interfacial Roughness and Stiffness of Coating Using URCPS-based Inverse Problem

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Aim at characterizing the adhesive-interfacial roughness and stiffness of thin coatings with unknown sound velocity and thickness, we propose an ultrasonic pressure reflection coefficient phase spectrum (URCPS) for identification of the interfacial roughness and stiffness utilizing material-oriented regularization. The URCPS is derived as a function of interfacial roughness and stiffness based on the phase screen approximation theory and springs model. A new objective function of least-squares coupled cross-correlation algorithm based on URCAS is developed to simultaneously inverse the velocity, thickness, interfacial roughness and stiffness of specimens. The effective detection range and detection accuracy of interfacial roughness and stiffness are analyzed through finite element method (FEM). A series of simulations were implemented on Ni-coating specimens with thickness of 400 μm and various interfacial roughness and stiffness. Ultrasonic experiments were carried out on two Ni-coating specimens through a flat transducer with optimized frequency of 15 MHz. Compared with the velocities measured by time-of-flight (TOF) method, the relative errors of inversed velocities were all less than 10%. The inversed thicknesses were in good agreement with those observed by optical microscopy with less than 10.9% and 7.6% error. The averaged interfacial roughness determined by the ultrasonic inversion method were 16.9 μm and 30.7 μm, respectively. The relative errors were 5.1% and 2.0% between ultrasonic and confocal laser scanning microscope (CLSM) method, respectively. The inversed interfacial stiffness Kn were in good agreement with those tested by tensile method. The proposed ultrasonic method is valid for nondestructive characterization of the thickness, velocity, interfacial roughness and stiffness of coatings.