Characterization of the Interface Roughness of Coatings Based on Ultrasonic Reflection Coefficient Amplitude Spectrum

Zhiyuan Ma¹², Wei Zhang¹, Jianying Gao¹, Li Lin¹*, and Sridhar Krishnaswamy², ¹NDT & E Laboratory, Dalian University of Technology, Dalian 116085, China and ²Center for Smart Structures and Materials, Northwestern University, Evanston IL 60208, USA

In order to nondestructively characterize the interface roughness of coatings effectively, the ultrasonic reflection coefficient amplitude spectrum (URCAS) involving interface roughness was derived based on the phase screen approximation theory [1]. The interface roughness was determined by a two-parameter inversion combined with a cross-correlation algorithm. For homogeneous coatings, the effects of ultrasonic wavelength $\lambda$, beam coverage, and shape variations of the coating on the roughness measurements were analyzed through numerical calculation. A series of simulations indicated that measurement errors were less than 10% when the relationship between interface roughness and wavelength satisfied $Rq=1.5\%\lambda\sim12\%\lambda$ approximately. For inhomogeneous coatings, the attenuation coefficient shows a non-negligible effect on the URCAS. A new URCAS suited for roughness measurement of inhomogeneous coatings was formulated by considering the relationship of attenuation coefficient $\alpha(f)$ on frequency $f$, which was determined by simulations. Ultrasonic experiments were carried out on standard roughness specimens and tungsten carbide (WC) coating specimen utilizing delay line transducers. The standard roughness specimens were shown in Fig 1, whose roughness $Rq$ were 8.5μm, 14.2μm, and 28.6μm measured by confocal laser scanning microscope (CLSM), respectively. The WC coating was sprayed on stainless steel by high velocity oxygen fuel (HOVF). Experimental results show that the roughness of standard roughness specimens obtained by the proposed ultrasonic measurement are in good agreement with the LCM observations, and the relative errors are less than 8.5%. For inhomogeneous WC coatings, the absolute error of roughness measurement is less than 2.5μm and the relative error is less than 20% between ultrasonic and metallographic methods.

![Figure 1. Photos of standard roughness specimens: (a) $Ra=6.3\mu m$; (b) $Ra=12.5\mu m$; (c) $Ra=25.0\mu m$](image)

References: