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Terahertz thickness measurement of multiple-layered coatings

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Abstract— Terahertz pulse reflectometry was employed to characterize the individual layers on metallic substrates. The autoregressive spectral extrapolation based on the modified covariance method was applied to enhance the axial resolution. All coating layers were resolved successfully and the calculated thickness of each layer based on deconvolved results shows a good agreement with the thickness value measured by eddy current technique, highlighting the promising application of terahertz technique on quality control among steel industries.

I. INTRODUCTION

To date, the conventional approach for monitoring the thickness of coating are eddy-current techniques and ultrasonic testing. However, these techniques have serious problems that limit the application among industries. For eddy current technique, it fails to provide the thickness of individual layer and the thickness distribution of the entire sample. For acoustic testing, the axial resolution is limited by the frequency. Terahertz imaging, as a nondestructive, non-ionizing, and noncontact approach, is a promising candidate for characterization of multiple-layer coatings on metallic substrate. Autoregressive spectral extrapolation based on the modified covariance method (AR/MCM) incorporated with wavelet denoising is also employed to separate those overlapped echoes reflected from each interface.

II. THEORETICAL BACKGROUND.

The autoregressive spectral extrapolation (AR) deconvolution is parametric approach to extend the bandwidth of deconvolved signals in frequency domain. In the AR process, assuming angular frequency ω_i within a window $\omega_{i_L} < \omega < \omega_{i_H}$, where ω_{i_L} and ω_{i_H} define the upper and lower frequency limits of the window, the AR model serves as a prediction filter to find data components outside the window for $i > i_H$, using the forward prediction equation

$$\hat{\omega}_i = - \sum_{k=1}^p a_k \omega_{i-k}$$

the backward prediction filters is used to find the missing components for $i < i_L$,

$$\hat{\omega}_i = - \sum_{k=1}^p b_k \omega_{i+k}$$

where a_k and b_k are coefficients of the AR forward and backward prediction filter, respectively.

III. RESULTS

Figure 1 shows that after the AR/MCM, the structure information can be extracted for all samples, and the thickness of each layer can also be estimated based on the corresponding optical distance and the refractive index.

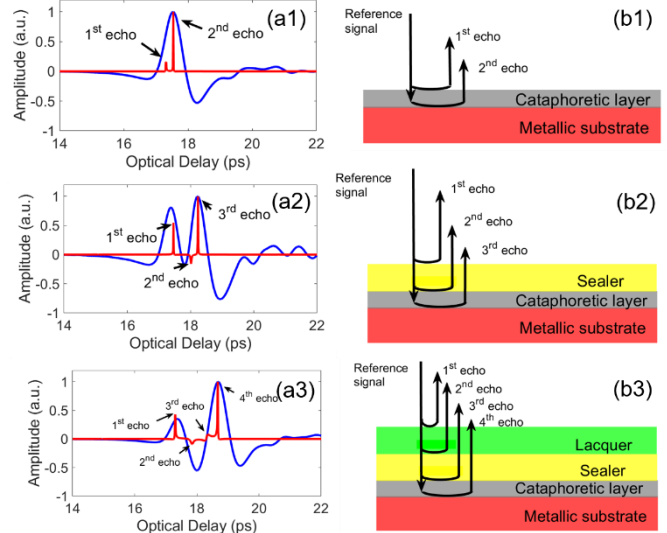


Fig. 1 The reflected signal (blue) and deconvolved result based on AR/MCM (red) from sample with one layer (a1), double layers (a2), and three layers (a3), with its corresponding representation of round-trip echoes in [(b1), (b2), and (b3)].

16 pixels distributed uniformly on the surface of samples are selected to testify the accuracy of the thickness of individual layer based on AR results. Excellent agreement with eddy-current measurements is obtained.

IV. SUMMARY

The THz measurement together with AR/MCM was employed to analyze the thickness of individual layer for stacked samples. The efficacy of AR/MCM method is verified numerically and experimentally for samples with various numbers of layers. The calculated thicknesses are consistent with the eddy-current measurement. The capability of providing the thickness distribution for individual layer with high resolution proves the promising application for monitoring the quality of coating on steel substrate.

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