Advanced Excitation Symmetry Analysis Method (ESAM) for improved automated ultrasonic testing of polished materials

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One of the strategic plans of the international NDT community is to define standards for developing advanced and digitalized non-destructive testing for automated set-up in mass production [1,2]. Excitation Symmetry Analysis Method (ESAM) are new coded signal processing tools exploring symmetry properties [3]. ESAM method aims to extract the nonlinearity from an ultrasound output by studying the property of symmetry of the transfer function. More precisely, the extraction of nonlinearity is done using basis function associated to a group which is associated to an a priori transfer function. As soon as the linear tomography uses the invariant properties of amplitude dependence, nonlinear tomography should exploit the invariance properties (or symmetry properties) of the complex system. Consequently, the invariance of the stationary properties of a complex medium would be supposed to be associated to a signature of the degradation, that will be extracted with advanced signal processing tools. The idea remains the same: studying the symmetry and more precisely the time reversal one and the inversion. A signal processing is used to measure discrepancies in the autocorrelation function (output signal called chirp coda) for two inputs: a signal and its inversion (pulse inversion). The experiments were done on different sample with and without cracks. It has been shown that when the nonlinearities are extracted from the chirp coda amplitude are non-negligible in crack area and nonlinearities are out of phase. Then, mixing symmetries like time reversal and pulse inversion enable the detection of defect that are difficult to detect with conventional ultrasound method. Indeed, for such crack a destructive mechanical analysis called Jomini is done where the material is polished and examined with microscope. The sensitivity improvement of chirp-coded signal processing has been validated in various domains. Coded excitation techniques, used in communication systems such as radar and sonar provide improved SNR without increasing the amplitude of excitation. The typical test equipment consists of a preamplifier Juvitek TRA-02 (0.02 - 5 MHz) connected to a computer, an amplifier ENI model A150 (55 dB at 0.3-35 MHz), a shear wave transducer Technisonic (2.25 MHz), and a longitudinal wave transducer Panametrics V155 (5 MHz). The experimental device was tested with the V3 calibration block, improved, and specially scaled in order to access to a wide range of multivalued parameters: mechanical properties, ultrasonic parameters (celerity and attenuation) and local geometric data. 1. Dos Santos, S. & Plag, C. Excitation Symmetry Analysis Method (ESAM) for Calculation of Higher Order Nonlinearities, Int. Journal of Non-Linear Mechanics, 43, 164-169 (2008). 2. Serge Dos Santos, Martin Lints, Denis Arruga, Ali Masood and Andrus Salupere, Standards for acousto-mechanical evaluation of multiscale hysteretic properties of complex material with nonlinear time reversal imaging https://www.ndt.net/article/ndt-slovenia2017/papers/49.pdf , in proc of the ICNDT 2017, Portoroz. ISBN 978-961-93537-3-8, pp. 49-57 (2017) 3. 2. Dvořáková, Z., Dos Santos, S., Kůs, V., and Převorovský, Z. (2023). Localization and classification of scattered nonlinear ultrasonic signatures in bio-mechanical media using time reversal approach. The Journal of the Acoustical Society of America, 154(3), 1684-1695.