NDC BEGINS WHERE NDT STOPS

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ultran

redefining
the limits of
ultrasound

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Dynamics of NDC

Ultrasonic nondestructive testing (NDT) has been practiced in industry for more than 70 years. However, NDC (characterization) applications of ultrasound are at best 15 years old. Characterization encompasses structure (micro and macro) and compositional analysis of materials, as well as defects, whereas the predominant goal of testing is the detection of overt flaws.

The old NDT practice is limited by its modus operandi. For example, the so-called "spurious indications" (due to scatter) actually contain useful information about a material's intergranular relationships, yet they are rejected in standard NDT practice. Applications of such methods are not suitable for the characterization of materials such as green, sintered, and polymerized ceramic matrix, and other materials varying in microstructure (density, porosity, grain size, etc.). Ultrasonic analysis for properties and microstructures requires objective- and material-suitable acoustics analogous to other methods that also utilize a wave as the characterizing tool.

These fundamental requirements in diagnostic ultrasound have been sucessfully achieved at *Ultran Laboratories, Inc.*, (USA). Two major contributions of immediate benefit to the materials industry are outlined.

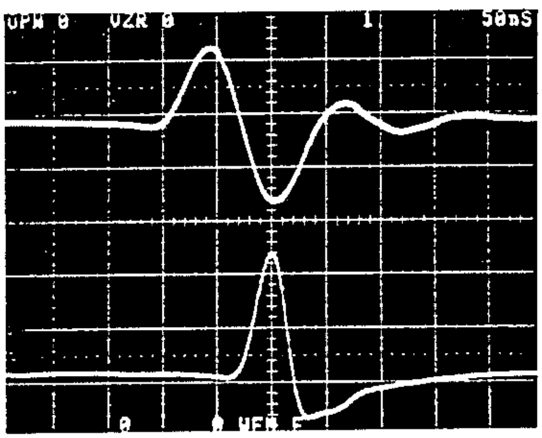

Fig. 1 Pulse width comparison of a conventional "broadband" and a "λ-series" 10 MHz transducer (top trace: conventional transducer pulse width: ~ 200 ns; bottom trace: λ-series transducer pulse width: ~ 60 ns; theoretical minimum pulse width at 10 MHz: 50 ns)

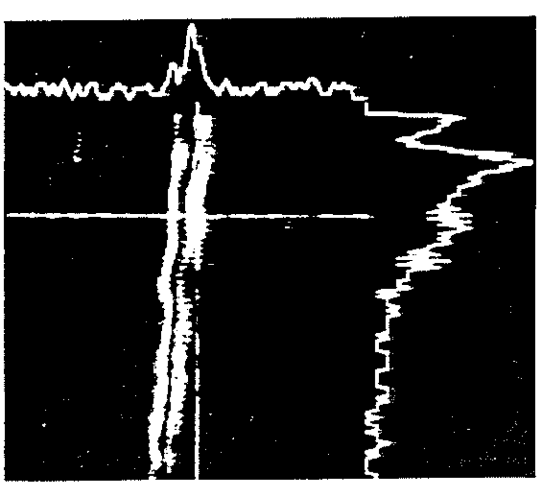

Fig. 2 Detection and profilometric characterization of an approximately 5 μm deep surface breaking crack in dense BeO substrate obtained by a 25 MHz geometrical acoustics device of 1,0 numerical aperture; cross-sectional profiles also determine the severity of damage in regions surrounding the defect

Ultra High Resolution Without VHF

Among critical requirements in ultrasonic NDC are the resolution of two "very closely" lying planes and the "detectability of the smallest" discontinuities in the shallow regions of a test material. It is almost universally assumed that, by increasing the frequency of incident ultrasound, both resolution and detectability are enhanced. In reality, this assumption is of limited use since very high frequencies (> 50 MHz) do not automatically mean "short ultrasonic pulses," a prerequisite for extraordinary resolution.

More than 10 years ago, Ultran developed half wavelength ($\lambda/2$) impulse ultrasound, popularly known as the λ-series transducers. Since highest resolution of two closely lying planes occurs at $d_{min} = \lambda/2$, these devices easily facilitate optimum resolution due to their near $\lambda/2$ time domain envelopes. λ-series transducers are characterized by pulse widths 3...4 times shorter than their conventional "broadband" counterparts (Fig. 1). In practical terms, if a particular resolution application requires 30 or 40 MHz frequency, it can be adequately and simply achieved by a mere 10 MHz λ-transducer. Besides resolution and detectability, this approach also enhances surface and bulk body ultrasonic imaging (Fig. 2) generated by Ultran system NDC 7000. From a practical standpoint, this is by far the most significant development in ultrasonic NDC.

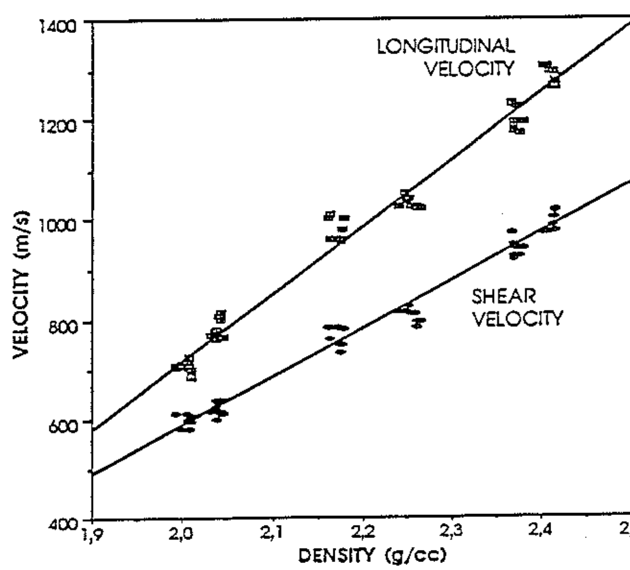

Fig. 3 Relationship of longitudinal and shear wave velocities with green Al_2O_3 density; these relationships were generated by Ultran system NDC 5000

Density ρ (from longitudinal velocity, V_l) = $(1938 + V_l)/1328$ (R = 0,99) [g/cm³]
Density ρ (from shear velocity, V_t) = $(1322 + V_t)/954$ (R = 0,99) [g/cm³]

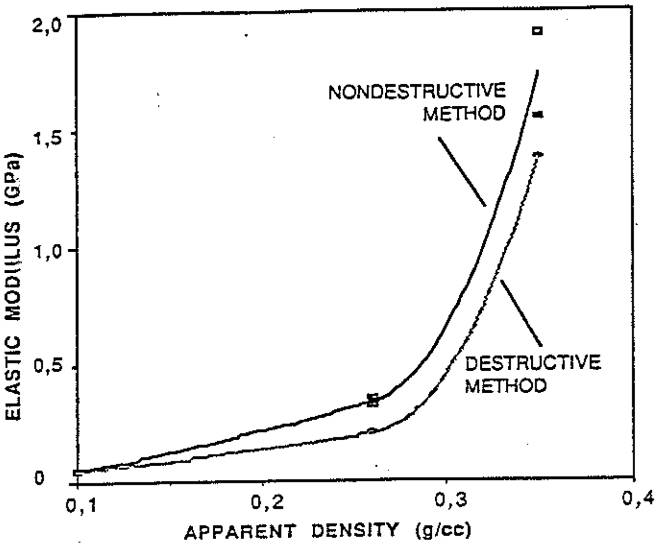

Fig. 4 Comparison of nondestructively and destructively measured elastic moduli of "rigid porous ceramic preforms" as a function of density; ultrasonic data was acquired by direct transmission dry coupling technique

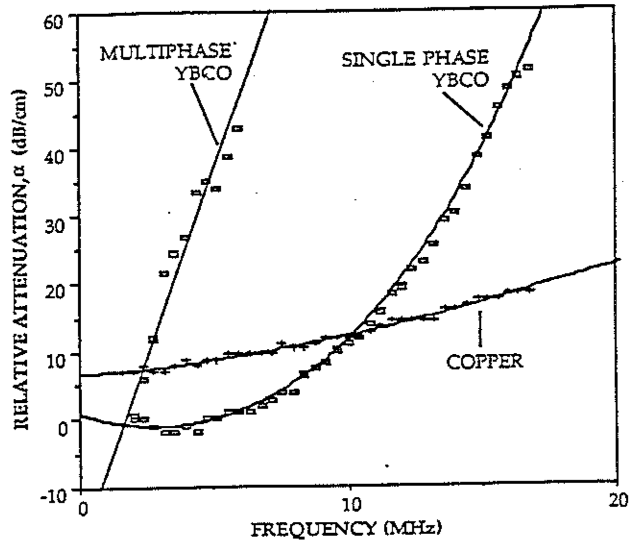

Fig. 5 Microstructure characterization of superconducting ceramics by dry coupling wideband ultrasonic spectroscopy; frequency dependence of ultrasonic attenuation is a sensitive function of material microstructure (Photos: Ultran Laboratories, Inc.)

NDC of Green, Porous, and Liquid-Sensitive Materials

Early detection of defects, density variations, and other weaknesses in those materials that pass through the powder compaction stage can save time and energy costs and can improve the material-making process. Due to the material fragility at this stage of processing, conventional "wet coupling" NDT practice cannot be used.

Similarly, porous (several ceramic, metal, and polymers and their composites) and liquid sensitive materials (electronic substrates, superconductors, etc.) cannot be reliably examined by wet coupling methods. In order to mitigate these limitations, Ultran developed novel "dry coupling" ultrasonic methods several years ago. By applying longitudinal and shear wave dry coupling transducers, their velocities and frequency dependence of ultrasonic attenuation can be easily measured (without the liquid mess) for practically all materials in order to generate significant process- and properties-related information (Figs. 3 – 5) generated by Ultran system NDC 5000. Dry coupling longitudinal and shear transducers have been perfected from < 200 KHz to > 30 MHz frequency and successfully used for accurate characterization for density, porosity, elastic properties, and other measurements on a wide range of materials.

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