# Acoustic harmonic generation at unbonded interfaces and fatigue cracks

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Citation: The Journal of the Acoustical Society of America **64**, S33 (1978); doi: 10.1121/1.2004155
View online: https://doi.org/10.1121/1.2004155
View Table of Contents: https://asa.scitation.org/toc/jas/64/S1
Published by the Acoustical Society of America

2:45

**N4. Acoustic harmonic generation at unbonded interfaces and fatigue cracks.** O. Buck and W. L. Morris (Rockwell International Science Center, P.O. Box 1085, Thousand Oaks, CA 91360)

The generation of a second-harmonic signal at a flat unbonded interface between two solids has been observed. This signal is caused by passage of a longitudinal acoustic wave across the interface. The harmonic amplitude depends upon the pressure applied normal to the interface and is largest close to zero pressure, as expected theoretically. The effect has also been used to detect the presence of microcracks on the surface of Al 2024, and Al 7075, developed during fatigue with an acoustic Rayleigh wave propagating along the fatigued surface. An alteration of the harmonic amplitude of the alloy has been observed after 5% of the expended fatigue lifetime, corresponding to the formation of microcracks on the alloy surface. The harmonic signal is observed to become progressively stronger as the microcracks propagate with additional fatigue loading. The results are especially encouraging in regard to future use of the technique to measure the remaining fatigue life of a component long before large cracks, detectable with other NDT techniques, develop prior to component failure.

3:00

**N5. Decay of a weak shock followed by a tail of arbitrary waveform.** David T. Blackstock (Applied Research Laboratories, The University of Texas at Austin, Austin, TX 78712)

Weak-shock theory is used to find the decay of a shock that is propagating into a quiet fluid. The tail, or flow field behind the shock, is assumed to be smooth but otherwise arbitrary. Let the time waveform of the pressure at the initial measurement point be given by $p = P_0 g(t)$, where $P_0$ is the initial pressure amplitude and $g(t)$ is the arbitrary tail function normalized so that $g(0) = 1$. For plane waves the dependence of the shock amplitude $P$ on distance $x$ is found from the following coupled equations: $Ax = [g(\phi_b)]^{-2} \int_0^{\phi_b} g(\lambda) d\lambda$ and $P = P_0 g(\phi_b)$, where $A$ is a constant and $\phi_b$ is the time-like parameter (for the shock) from the Earnshaw solution. For example, if $G = \exp(-at)$ (an exponential tail), the coupled equations yield $P = (P_0/Ax)[(2Ax + 1)^{-1/2} + 1]$, in agreement with P. H. Rogers' result [J. Acoust. Soc. Am. **62**, 1412–1419 (1977)]. Solutions have also been obtained for the model tail functions described by J. W. Reed [J. Acoust. Soc. Am. **61**, 39–49 (1977)]. For spherical waves replace $x$ by $r_0 \ln(r/r_0)$ where $r$ is radial distance and $r_0$ is the initial measurement distance. [Work supported by ONR and AFOSR.]

3:15

**N6. Asymptotic decay of periodic spherical waves in dissipative media.** Don A. Webster and David T. Blackstock (Applied Research Laboratories, The University of Texas at Austin, Austin, TX 78712)

In studies of plane periodic waves of finite amplitude in dissipative media, it has been found that if $n\alpha_1 < \alpha_n$, the $n$th harmonic pressure component $p_n$ decays asymptotically as $\exp(-n\alpha_1 x)$, not as $\exp(-\alpha_n x)$, where $\alpha_n$ is the small signal absorption coefficient for the $n$th harmonic component. Since generally $n\alpha_1 < \alpha_n$, this means that the nonlinearly generated $n$th harmonic decays more slowly than would be expected from linear theory. Moreover, save for the fundamental, no distance is ever reached at which the linear theory decay is established. In this paper the spherical wave problem is addressed. The results are based on an asymptotic solution of Burgers' equation. It is found that for both weak and strong waves the harmonics decay as $\exp(-n\alpha_1 r)/r^n$. The apparent absorption is the same as in the plane wave case. The apparent geometrical spreading, however, is $r^{-n}$, not $r^{-1}$. The asymptotic decay is still, however, slower than would be expected on the basis of linear theory. [Work supported by NASA, AFOSR, and ONR.]

3:30

**N7. On the road to computational acoustics.** H. D. Hogge (Poseidon Research, 11777 San Vicente Boulevard, Suite 641, Los Angeles, CA 90049)

Acousticians have largely overlooked the methods of *computational fluid dynamics* (i.e., the direct numerical integration of the nonsteady, compressible continuity, momentum, and energy equations) because of the success of the linearized normal-mode approach and because the numerical viscosity inherent in traditional computational methods damp out acoustic disturbances at an unrealistic rate. The advantage of the computational approach is that it allows inclusion of physical phenomena excluded from the linearized normal-mode approach such as nonlinear convection, nonisentropic losses, and phase change effects. The recent development of SHASTA, a relatively nondiffusive computational method [J. P. Boris and D. L. Book, J. Comp. Phys. **11**, 38–69 (1973)], has made possible the accurate solutions to acoustics problems. SHASTA is applied to a piston driven shock wave, an acoustic traveling wave, and an acoustic standing wave. The solutions of these problems by other standard numerical schemes are shown for comparison. It is found that only SHASTA is acceptable for all problems considered. As a practical example the computational approach is applied to the acoustic-wave/entropy-wave interaction associated with reflections from a choked flow wall. [Work supported by DARPA.]

3:45

**N8. Effect of ultrasound on liquid flow through porous materials.** Harold V. Fairbanks (Department of Chemical Engineering, West Virginia University, Morgantown, WV 26506)

The results of studies where ultrasound was introduced into three different processes involving liquid flow are reported. The systems include (1) crude oil flow through porous sandstone, (2) filtration of slurries containing fine particles, and (3) drying of moist powdered material. It was found that the introduction of ultrasound into these processes produced easier movement for the liquid phase and in case of the slurries, aided in the coagulation of the particles. The introduction of ultrasound appears to change the normal viscous liquid flow movement to a plug like type of liquid flow. The ultrasonic frequency used was 20 KHz with intensities up to 160 dB.

4:00

**N9. Subharmonic response of ultrasonically driven liquid helium.** R. F. Carey, J. A. Rooney, and C. W. Smith (Department of Physics, University of Maine, Orono ME 04473)

The subharmonic spectrum of liquid helium was studied using pairs of PZT-4 thickness mode transducers resonant at 1, 3, or 10 MHz. One transducer serves as the sound source and the acoustic response of the liquid is measured by spectral analysis of the signal detected by the second transducer. Above specific displacement amplitudes the subharmonic and its associated ultrahomonics can be detected. Measurements of the threshold amplitudes for these spectral components indicates at most a weak temperature dependence for temperatures well below the lambda point $T_\lambda$. Significant changes in subharmonic amplitude occur near $T_\lambda$. Specifically, for a sound amplitude of 75 Å using the 1-MHz transducers we observe that the amplitude of the subharmonic increases by at least 10 dB when the temperature is decreased from $(T_\lambda + 5mK)$ to $(T_\lambda - 5mK)$. In addition, analysis of the spectral broadening of the subharmonic provides information about the fluid and turbulent motions within the sample vessel. Observations will be discussed in relation to mechanisms for subharmonic generation. [Work supported in part by the Air Force Office of Scientific Research.]