DAVI-GF 77-1590

REPRINTED FROM
HIGH-PRESSURE RESEARCH
Applications in Geophysics

ACADEMIC PRESS, INC.
NEW YORK SAN FRANCISCO LONDON

TRANSDUCER AND BOND PHASE SHIFTS IN ULTRASONICS, AND THEIR EFFECTS ON MEASURED PRESSURE DERIVATIVES OF ELASTIC MODULI

G. F. DAVIES
Department of Geological Sciences
University of Rochester
Rochester, New York 14627

R. J. O'CONNELL
Department of Geological Sciences
Harvard University
Cambridge, Massachusetts 02138

Abstract

Phase shifts introduced into ultrasonic signals by the presence of transducers and bonds at sample surfaces have been measured using an automated variable frequency ultrasonic interferometer. At zero pressure, phase shifts have been resolved due to transducers, bonds between transducers and samples, and bonds between buffer rods and samples. Observed transducer-bond-sample phase shifts are in good accord with theoretical estimates, and bond thicknesses of about 0.3 μ are inferred. Measurements to 7 kbar are consistent with theoretical estimates of the effect of pressure on transducer-bond-phase shifts. Providing the frequency of the ultrasonic signal is within a few percent of the resonance frequency of the transducer, and the effect of pressure on the transducer resonance frequency is accounted for (as recommended by *McSkimin*, [1961]), the effect of the bond phase shift on the measured pressure derivative of the elastic modulus should amount to less than about 0.02. If the frequency deviates substantially from the transducer resonance frequency, especially at zero pressure, errors of the order of 0.25 could be incurred in the pressure derivatives. The nonlinearity of transducer-bond phase shifts could cause significant errors in second-pressure derivatives, even under favorable conditions. For shear waves at zero pressure, the observed buffer-bond-sample phase shifts are consistent with those estimated theoretically for a bond of about 1 μ thickness. For compressional waves at zero pressure, phase shifts are very sensitive to the buffer-sample contact: large differences in phase are observed between dry lapped, "wetted," immersed, and resin-bonded contacts. The sources of these differences are not fully understood, but they may be due to variations in contact area produced by the ultrasonic wave. "Normal" buffer-sample bonds are estimated to be capable of affecting measured pressure derivatives by about 0.25. The behavior of the anomalous

buffer-sample phase shifts under pressure is unknown, but the shifts could easily give rise to substantial errors in measured pressure derivatives.

I. INTRODUCTION

The geophysical objective of ultrasonic measurements is to be able to extrapolate laboratory measurements of elastic properties and density to the pressure and temperature conditions of the earth's deep interior. For these extrapolations to be useful, considerable accuracy is required of the measurements. In principle, the widely used pulsed ultrasonic techniques [*McSkimin*, 1957; 1961], or variations thereof, are capable of measuring elastic velocities to an accuracy of at least 0.05%, and of detecting relative changes in elastic velocity of even smaller magnitude [*McSkimin*, 1956]. In practice, however, this accuracy apparently has not usually been achieved.

Table 1 compares the results of different measurements of the same material for several materials: the spread in results for elastic moduli is commonly in the range 0.2-1%, and greater in some cases. The velocity measurements taken to pressures of the order of 10 kbar would show changes of the order of a few percent. Thus, in principle, the measured pressure derivatives of elastic modulus should be accurate to a few percent at least. It can be seen in Table 1, however, that discrepancies of the order of 10% commonly occur. For materials of geophysical interest, an uncertainty of this magnitude produces an uncertainty of the order of 10% in elastic velocities extrapolated to 1 Mbar, and this uncertainty is much too large for the extrapolation to be useful in interpreting the seismically observed elastic velocities in the deep mantle. It is thus of interest to determine the source of the discrepancies.

This paper reports on the effects of phase shifts in ultrasonic waves caused by the presence of transducers, buffer rods, and bonding material at the surface of a sample. These phase shifts are one possible source of the discrepancies discussed above. Theoretical and experimental determination of buffer-bond phase shifts at zero pressure were considered by *McSkimin* [1950; 1957]. Transducer-bond phase shifts were considered by *Redwood and Lamb* [1956] and *McSkimin* [1957; 1961]; the effects of pressure and temperature were considered by *McSkimin* [1961] and *McSkimin and Andreatch* [1962]. In this study the phase shifts were observed over a wide frequency range using ultrasonic interferometry, and the effects of pressure are considered in more detail.