THE INFLUENCE OF TENSILE STRESSES ON THE VELOCITIES OF PROPAGATION OF LONGITUDINAL AND TRANSVERSE ELASTIC WAVES IN ROCKS

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THE INFLUENCE OF TENSILE STRESSES ON THE VELOCITIES OF PROPAGATION OF LONGITUDINAL AND TRANSVERSE ELASTIC WAVES IN ROCKS

The extensive experimental material now available on studies of the influence of hydrostatic pressure (^1) and uniaxial compression (^2, ^3) on the velocities of propagation of longitudinal elastic waves in rocks cannot, however, give a complete picture of the state of rocks under natural conditions, since pressure in the subsurface is not limited only to compressive loads. Even at very great depths in the earth' s crust tensile forces occur (^4). The presence of tensile stresses is still more natural in the zone of influence of mine workings during underground mining of mineral deposits.

In this connection, under laboratory conditions, studies were carried out of the influence of tensile loads on the velocities of propagation of longitudinal and transverse elastic waves in a number of rocks. The experimental arrangement, including the electronic and mechanical parts, is shown in Fig. 1. A rock specimen 1 in the form of a cylinder 30-31 mm in diameter and about 100 mm long is fastened, by means of a cementing material 2 (quartz-alumina, hardening temperature about 70°), in grips 3 shaped as washers 20 mm high with an internal opening of 34 mm; to improve adhesion of the quartz to the metal, the surface of the opening is made in the form of a coarse thread. The tensile force from a standard tensile-testing machine is transmitted to the specimen by the grips through a system of hinged rods 4. To avoid the appearance of bending moments during installation of the specimen in the grips and its loading, a guide cylinder 5 is used.

Fig. 1. Diagram for studying parameters of elastic waves in rocks under tension: 1—specimen, 2—quartz, 3—grip, 4—rod, 5—guide cylinder, 6—piezoelectric transducer, GI—video-pulse generator, LZ—electrical delay line, S1-8—universal oscilloscope.

The electronic part of the arrangement includes a video-pulse generator (blocking oscillator), an S1-8 oscilloscope, a sweep-delay unit of the oscilloscope (mul-

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tivibrator), and piezoceramic transducers 6. External triggering of the oscilloscope sweep through a continuously discrete delay line made it possible to extend the time capabilities of the S1-8 oscilloscope, which has good dynamic characteristics. The maximum errors did not exceed 1% in the initial determination of the veloc—

of elastic waves by the first arrival of the signal and 0.2% when determining their change with pressure from the displacement of the crest of the first half-period of the signal. At the same time, the signal amplitude was also measured from the maximum swing of the first wave packet (3-5 periods), with an error of 1-2%.

Combined-type transducers (^{5}) for P- and S-waves made of TsTS-19 piezoceramic, having natural frequencies of about 900 kHz for longitudinal oscillations (disk diameter 20 mm, height 2 mm) and about 500 kHz for shear oscillations (plate 18 × 6 × 2 mm), were attached directly to the free ends of the specimen by means of salol.

The experiments were carried out on specimens of three main rock types—igneous, metamorphic, and sedimentary (Table 1). From the experimental results, curves were constructed for the increments of velocities

$$\Delta v_{P,S} = \frac{v_\sigma - v_0}{v_0} \cdot 100\%$$

and amplitudes

$$\Delta A_{P,S} = \frac{A_\sigma - A_0}{A_0} \cdot 100\%$$

as functions of tensile stresses.

Figure 2a shows curves of the increments of velocities and amplitudes of longitudinal and transverse waves in Dzhezkazgan sandstone under tensile stresses. For comparison, the results of a study of the influence of compressive loads on the velocity and amplitude of the longitudinal wave are also given (Fig. 2b). In

Fig. 2. Curves of the dependence of the parameters of longitudinal (P) and transverse (S) waves in Dzhezkazgan sandstone on tensile (a) and compressive (b) stresses: 1 and 2—respectively, increments of the velocity and amplitude of P-waves; 3 and 4—the same for S-waves

Figure 2: Fig. 2. Curves of the dependence of the parameters of longitudinal (P) and transverse (S) waves in Dzhezkazgan sandstone on tensile (a) and compressive (b) stresses: 1 and 2—respectively, increments of the velocity and amplitude of P-waves; 3 and 4—the same for S-waves

this case, in order to reduce the influence of contact conditions, the amplitude increment was determined as

$$\Delta A_P = \frac{A_\sigma - A_{50}}{A_{50}} \cdot 100\%$$

(where A_{50} is the signal amplitude at 50 kG/cm^2).

Fig. 2. Curves of the dependence of the parameters of longitudinal (P) and transverse (S) waves in Dzhezkazgan sandstone on tensile (a) and compressive (b) stresses: 1 and 2—increments, respectively, of the velocity and amplitude of P-waves; 3 and 4—the same for S-waves.

When a specimen is stretched, the velocities and amplitudes of elastic waves decrease; moreover, as the load increases, the gradients of their change grow continuously up to failure of the specimen. However, the overall changes under tension are smaller than under compression (for Dzhezkazgan sandstone they are comparable). The changes in v_S are 2-3 times smaller than those in v_P, both under compression and under tension. The changes in the amplitudes of elastic waves exceed the changes in velocities by an order of magnitude, and this difference is greater under tension than under compression. Under tension, the changes in A_S are greater than in A_P, this difference being most substantial for Dzhezkazgan sandstone.

Under compression of a specimen, the velocities and amplitudes of elastic waves increase; but with increasing load the gradients of their change, gradually decreasing, tend toward zero under hydrostatic pressure and change sign to the opposite in the case of uniaxial compression when the limiting loads are reached (in brittle rocks, upon reaching the strength limit, the velocities and amplitudes fall practically instantaneously).

The investigations carried out showed that the presence of tensile stresses in the Earth' s crust can have a substantial effect on the measured parameters of seismic or ultrasonic waves, especially

Table 1

Rocks	ρ, g/cm^3	Porosity, %	v_P, m/s	v_S, m/s	E, N/m^2 10^{-10}	G, N/m^2 10^{-10}	Poisson's ratio	Tension σ, kg/cm^2	Tension $-\Delta v_P$, %	Tension Δv_S, %	Tension ΔA_P, %	Tension ΔA_S, %	Compression σ, kg/cm^2	Compression Δv_P, %	Compression ΔA_P, %
Novodanilovskii granite	2.6	3.5	5050	2970	5.65	2.28	0.24	67	9.0	4.0	23	35	1430	18.3	150
Dzhezkazgan sandstone	2.67	1.5	5150	3050	6.1	2.5	0.23	170	6.0	1.7	70	90	1700	7.4	40
Kuzbass sandstone	2.6	2.5	4100	2600	4.15	1.8	0.15	89	3.5	2.0	66	80	1250	18.0	74
Ural white marble	2.67	0.5	4400	2700	4.67	1.95	0.195	42	9.5	2.3	–	–	715	31.0	270

on the amplitudes of S-waves. Use of the results of this work will contribute to increasing the reliability and informativeness of seismoacoustic methods for studying rock masses.

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