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Nonlinear Evolution of the Pulses of Elastic Waves in Geological Materials

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Abstract : Nonlinear evolution of broadband ultrasonic pulses passed through the rock specimens is studied using the apparatus 'GEOSCAN-02M'. Ultrasonic pulses are excited by the pulses of Q-switched Nd:YAG laser with the time duration of 10 ns and with the energy of 260 mJ. This energy can be reduced to 20 mJ by some light filters. The laser beam radius did not exceed 5 mm. As a result of the absorption of the laser pulse in the special material – the optoacoustic generator–the pulses of longitudinal ultrasonic waves are excited with the time duration of 100 ns and with the maximum pressure amplitude of 10 MPa. The immersion technique is used to measure the parameters of these ultrasonic pulses passed through a specimen, the immersion liquid is distilled water. The reference pulse passed through the cell with water has the compression and the rarefaction phases. The amplitude of the rarefaction phase is five times lower than that of the compression phase. The spectral range of the reference pulse reaches 10 MHz. The cubic-shaped specimens of the Karelian gabbro are studied with the rib length 3 cm. The ultimate strength of the specimens by the uniaxial compression is (300±10) MPa. As the reference pulse passes through the area of the specimen without cracks the compression phase decreases and the rarefaction one increases due to diffraction and scattering of ultrasound, so the ratio of these phases becomes 2.3:1. After preloading some horizontal cracks appear in the specimens. Their location is found by one-sided scanning of the specimen using the backward mode detection of the ultrasonic pulses reflected from the structure defects. Using the computer processing of these signals the images are obtained of the cross-sections of the specimens with cracks. By the increase of the reference pulse amplitude from 0.1 MPa to 5 MPa the nonlinear transformation of the ultrasonic pulse passed through the specimen with horizontal cracks results in the decrease by 2.5 times of the amplitude of the rarefaction phase and in the increase of its duration by 2.1 times. By the increase of the reference pulse amplitude from 5 MPa to 10 MPa the time splitting of the phases is observed for the bipolar pulse passed through the specimen. The compression and rarefaction phases propagate with different velocities. These features of the powerful broadband ultrasonic pulses passed through the rock specimens can be described by the hysteresis model of Preisach-Mayergoyz and can be used for the location of cracks in the optically opaque materials.

Keywords : cracks, geological materials, nonlinear evolution of ultrasonic pulses, rock
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