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MATHEMATICAL MODEL OF GENERATION AND PROPAGATION OF SLOW DEFORMATION FRONTS

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ABSTRACT

In the present paper, the hypothesis that all the perturbations of the stress-strain state observed in solids and in geomedia propagating in the form of slow deformation fronts have a common physical nature. The paper proposes a mathematical model that describes the related processes of the evolution of a stress-strain state in a loaded unstable elastoplastic medium and the formation and propagation of slow deformation fronts.

Keywords: slow deformation fronts, numerical modelling, critical states, geomedia.

INTRODUCTION

As is known, perturbations in continuous media are transmitted by stress waves with sound velocities. There are also waves of plasticity (the Kol'skii waves), whose velocities are noticeably smaller, but close in order. The velocities of tectonic flows, which are determined by geological data and GPS measurements, are no more than a few cm / year, 14-15 orders of magnitude lower than the sound velocities and characterize creep (Goldin, 2002). These movements cannot be interpreted as waves. In the physics of plasticity, slow deformation processes - the Lüders fronts, propagating in the form of plasticity waves have been studied sufficiently well. The velocities of these disturbances occupy an intermediate value and are of the order of 2×10^{-5} m/s. Similar deformation perturbations were found in geomedia. The concept of Earth's deformation waves or "slow motions", whose velocities are 5...7 orders lower than the sound velocities and 7...8 orders higher than the typical velocities of tectonic flows have developed in the Earth sciences over the past 50 years (Goldin, 2002; Bykov, 2000, 2005; Guberman, 1979; Malamud, 1983; Kuzmin, 2012). It is actually a matter of stress-strain state perturbations in geomedia propagating from the disturbance source (usually the boundaries of tectonic plates and faults of different scales) and is interpreted as a wave. These slow deformation fronts in various materials and geomedia are interpreted as autowave processes, caused by the instability of the loaded damaged medium, its cooperative response and parametric excitation (Guberman, 1979; Kuzmin, 2012).

RESULTS OF NUMERICAL SIMULATION

A mathematical model describing the processes of joint generation and propagation of both sound stress waves and slow deformation perturbations of an inelastic nature includes a system of nonlinear equations of solid mechanics, kinetic equations for generating of inelastic deformations and/or damages, positive and negative feedbacks governing stability/instability of the deformation process (Makarov, 2016). This system of equations was solved numerically (Makarov, 2016).

In calculations, the fronts of autowaves were determined from the rate of inelastic strain in the moving band of localized deformation (autowave), where the rate of inelastic strain is several orders of magnitude higher than the mean background (Figure 1). Figure 1 demonstrates two fronts formed in grips that move towards each other. Their interaction is similar to the interaction of solitons. They either repel each other, or penetrate each other.

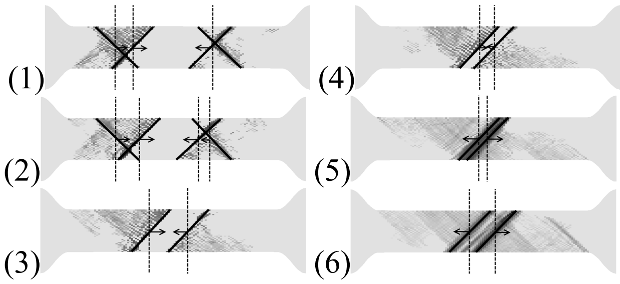

Fig. 1 - Spatial distribution of the inelastic deformation fronts and their soliton-like interaction for various consecutive times (1) - (6) in a plastic sample upon its uniaxial tension.

Formed autowaves of deformation, interacting as solitons, is the result of a cooperative self-consistent in space and time process of self-organization in a stressed media.

The properties of the resulting deformation solitons are similar both to the properties of solitons obtained in the solutions of the Korteweg-de-Vries equation, and to kinks-solutions of the Sin-Gordon equation. Slow deformation fronts can move with different velocities depending on the level of acting stresses and can stop, forming the bands of localized inelastic deformation, can then resume motion.

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