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On Identification Of Stresses In Tectonic Plates: Plastic And Elastic Models

P. Haderka and A.N. Galybin

Wessex Institute of Technology, UK (agalybin@wessex.ac.uk / Fax: +442380292853 / Phone: +442380293223)

This study is aimed at the development of theory and numerical methods for determination of stresses in elastic and ideal plastic regions. The use of data on stress orientations as boundary conditions is the main feature of this research that differs it from conventional approaches to the stress identification in the earth's crust.

Galybin and Mukhamediev (1999, JMPS) studied a non-classical boundary value problem, BVP, of elasticity in which principal directions and curvatures of stress trajectories have been used as the set of boundary condition while no data on stress magnitudes have been employed. Such formulation leads to non-uniqueness of the solution for the stress tensor, which, as shown, is considered as a linear combination of particular solutions with arbitrary coefficients. The number of solutions is finite and it is fully determined form the analysis of rotations of principal orientations after the complete traverse of the boundary. Based on this approach a number of applications for identification of stresses in particular regions of the lithosphere have been reported at the previous EGU meetings. In this study we focus on the case of ideal plasticity, which (together with the elastic assumption) can be considered as another limiting case for modelling of real stress states in the earth's crust. The Antarctic plate has been chosen as an example in order to provide comparisons between plastic stress field and elastic one presented earlier by Galybin (EGU, 2005). This choice is also justified by the data (Reinecker, et al. (2005) The release 2005 of the World Stress Map, available online at www.world-stress-map.org), which are mostly known at the plate margins, while just a few data are located inside the plate. Such structure of the data makes it impossible to construct stress trajectories based on interpolation as proposed, for example, in Hansen and Mount (1990, J Geophys Res) but requires consideration of specific BVPs.

Two BVPs have been considered for a finite (interior) domain. In both of them the domain is assumed to be ideal plastic. The first BVP is for interior domain only; it involves principal directions and curvature of stress trajectories as two boundary conditions. The second BVP assumes continuity of tractions across the boundary between interior and exterior domains, the latter models interaction with adjacent tectonic plates and assumed to be elastic. Principal directions form both sides of the contour are used as the second set of boundary conditions, which completes formulation.

It is shown that for the case of ideal plasticity the pattern of stress trajectories can be found uniquely by integration of a partial differential equation of hyperbolic type derived from the equations of equilibrium. Since the maximum shear stress is a known constant, it allows one to find the complete stress tensor with an accuracy of one additive constant.

Numerical implementation is based on the methods developed for ideal plastic bodies and assume transformation of differential equations into finite differences followed by iterative procedure applied for the Cauchy's BVP. The procedure also uses general solutions (Hencky's integral in elasticity and complex potentials in elasticity) which are sought in accordance with the Trefftz method. A numerical code have been developed by using the Matlab software and verified against known results in order to ensure the accuracy of analysis. After that it has been applied for the case of simplified contours with synthetic and real data and to the case of Antarctic plate (with real data interpolated along the boundary). The results indicate substantial difference between elastic and plastic models, which will be demonstrated in detail during the presentation.

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