SOURCE PARAMETERS FOR STICK-SLIP AND TENSILE-Crack MECHANISMS AND POSSIBILITIES OF THEIR SEISMIC DISCRIMINATION

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1. INTRODUCTION

According to recent hypotheses of the mechanism of tectonic earthquakes, besides shear dislocation along an existing fault, also fast tensile fracturing of the medium in the vicinity of a tectonic stress-concentrating fault is widely accepted as a mechanism which can contribute to energy release in foci of shallow earthquakes. Even though both mechanisms, i.e. stick slip along an existing fault and tensile cracks at its tips, have been intensively studied from the early sixties (for an overview of recent experimental stick-slip studies see, e. g., [1, 2], references concerning tensile fracturing can be found, e.g., in [2, 3]), direct measurements of seismoactivity of tensile cracks in physical models have only been performed recently [4—6]. Although the very existence of tensile cracks in reality seems to be unambiguously proved, their seismoactivity remains an open question. It is the aim of this paper to consider if the seismoactivity of real tensile cracks can be proved on the basis of a standard interpretation of seismic records.

Standard seismic data processing, from the viewpoint of source characteristics, is now limited to determining phenomenological source parameters only — seismic moment, average slip and stress drop. Although these characteristics represent a higher level of description of the source than previous one-parameter models just based on the quantity magnitude, they are of a general character only and do not reflect the details of the physical processes taking place in a focal region. Naturally, the question arises if, on the basis of these parameters, a conclusion about the very mechanism of the source can be drawn, particularly, if our attention is limited to shallow earthquakes, if seismic sources of the common shear mechanism and mechanism of tensile fracturing can be discriminated.

The purpose of this paper is to determine the source parameters — stress drop, seismic moment and radiation pattern — of seismic sources represented by a stick-slip event and tensile-crack generation. Considering the values of these parameters determined for both mechanisms, an
attempt is made to utilize them as discrimination criteria applicable to the routine interpretation of seismic records. A model technique, analogous to that described in [7, 8], makes it possible to model both seismoactive events in a single model of a linear fault with friction and to determine the source parameters, seismic moment and stress drop, by direct measurements, i.e. contrary to common seismological practice, without seismic records. This method enables us to draw some conclusions about source parameters, determined on the basis of the standard seismological procedure, being incorrect, if the source is not due to a pure shear mechanism.

2. METHOD

Model measurements were performed on physical models made of perspex. Square plates 90 × 90 mm, 8.0 ± 0.2 mm thick, were used as models. In the centre of the plates, linear diagonal slits, 20 mm long, were cut and a special frictional contact allowing stick-slip generation was prepared (see [2, 8]). To load the model, a controlled hydraulic loading device operating with a loading rate of 0.4 MPa s\(^{-1}\) was used. For the stick-slip study, the models were loaded with 20—25 kN, for the tensile-crack study loading with 50—60 kN was necessary to initiate the tensile cracks.

Theoretical calculations concerning the stress and the displacement fields in the vicinity of the fault plane were performed using Muskhelishvili’s theory of plane stress [9, 10]. The fault was mathematically approximated by a linear discontinuity with ideally sharp tips. As for the calculations of radiation patterns of both the sources considered, i.e. the tensile-crack and stick-slip event, formulas of Hirasawa and Stauder [11] and Savage [12] for radiation from finite moving sources, represented by unilateral tensile and shear dislocations, were used.

3. RESULTS

3.1. Stress drop

Stress drop is a source parameter defined as the difference of the initial and final average stress on a fault plane. In determining the stress drop for two considered sources of different mechanisms, we must consider the stress component which is responsible for generating each mechanism, i.e. the tensile-stress component in the tensile-crack source and the shear stress in the stick-slip event.

3.1.1. Stress drop for the tensile-crack mechanism

As it was found in [7], the initiation and growth of a tensile crack occurs in two stages — the stage of fast propagation accompanied by seismic energy radiation and the stage of slow stable growth. It is evident that stress calculations must be performed on the fast stage of the crack path only.

A tensile crack has stress-free inner boundaries, thus the stress drop equals directly the value of the average tensile stress on the plane of the future crack; in a two-dimensional approximation on the length of future crack \(l^{*}_{TC}\):

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\Delta \sigma = (l^{*}_{TC})^{-1} \int_{0}^{l^{*}_{TC}} \sigma \, dr.
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