Inversion of waveform from the data of six moderate strong earthquakes in Chinese mainland to seismic moment tensors and source mechanism

Shao-Dong FANG (方韶东) and Pei-Shan CHEN (陈培善)  
Institute of Geophysics, State Seismological Bureau, Beijing 100081, China

Abstract

Based on Generalized Seismic Ray Theory (Helmberger, 1968), a new quickly linear inversion method from the data of seismic waveform to seismic moment tensor and source mechanism for domestic earthquake is studied in this paper. Six moderately strong earthquakes which occurred in Chinese mainland in the past few years are studied. The seismic source parameters of these earthquakes, seismic moment tensors, scalar seismic moments, fault plane solutions and source time functions etc. are obtained.

Key words: seismic moment, fault plane solution, linear inversion, theoretical seismogram.

Introduction

Since Gilbert first introduced the concept of seismic moment tensor in 1970, with developments of theoretical seismogram, seismic source parameters have been able to be quickly determined abroad at present. For example, in Harvard University, United States, Dziewonski et al. (1981, 1983, 1985) have calculated Centroid Moment Tensors (CMT) of all earthquakes with $M_s \geq 5.4$ in the whole world. They have developed a set of half-automatic program which can be used to deal with the data of earthquakes for magnitude over 5.4 recorded by highly sensitive SRO network. When CMTs are solved, the informations of body wave train including multiple reflection waves and converted waves of P wave and S wave are used. They deliver the results of CMT solutions to NEIC every month. EDR bulletins published by NEIC will carry their results.

Although the China Digital Seismograph Network (CDSN) has been built and worked for a long time, the developments on this field are slow in China. Shu et al. (1983) determined the seismic source parameters of Bohai earthquake from the data of far-field (epicentral distance more than 30°) P-wave waveform. Yao (1985) proposed a seismic waveform inversion procedure for determination of fault plane solution. Two kinds of method are the least squares waveform inversion essentially, the error function is determined by the cross-correlation coefficient of an observed record and a synthetic seismogram, only the waveforms are identical. In this paper, a new fast linear inversion method from the data of seismic waveform to seismic moment tensor and source mechanism for domestic earthquake is studied so that this kind of work becomes a routine operation and fairly reliable seismic source pa-

rameters are presented to numerous researches as soon as possible.

The epicentral distances of domestic earthquakes recorded by CDSN are major less than 30° and far-field data aren't enough. So, we must use the data of waveform in the varying epicentral distance. In view of above-mentioned reasons, generalized seismic ray theory (Helmberger, 1968) is used in this paper. In order to suit Chinese practical conditions, we study a new fast linear inversion method to determine seismic moment tensor and source mechanism for domestic earthquake. On this method, seeing not only waveform but also absolute amplitude must be coincident. The results are very sensitive to quality of the data.

Method

In cylindrical coordinates, the vertical, radial and tangential displacements of shear dislocation can be expressed as follows (Helmberger et al., 1968, 1974, 1978, 1980, 1983):

\[
\begin{align*}
    w(r, \theta, z, t) &= \frac{M_0}{4\pi \rho} \frac{d}{dt} \left[ D(t) \ast \sum_{j=0}^{2} A_j(\lambda, \delta, \theta) W_j(t) \right] \\
    q(r, \theta, z, t) &= \frac{M_0}{4\pi \rho} \frac{d}{dt} \left[ D(t) \ast \sum_{j=0}^{2} A_j(\lambda, \delta, \theta) Q_j(t) \right] \\
    v(r, \theta, z, t) &= \frac{M_0}{4\pi \rho} \frac{d}{dt} \left[ D(t) \ast \sum_{j=1}^{3} A_{j+3}(\lambda, \delta, \theta) V_j(t) \right]
\end{align*}
\]

where

\[
\begin{align*}
    A_0(\lambda, \delta, \theta) &= \frac{1}{2} \sin \lambda \sin 2\delta \\
    A_1(\lambda, \delta, \theta) &= \cos \lambda \cos \delta \cos \theta - \sin \lambda \cos 2\delta \sin \theta \\
    A_2(\lambda, \delta, \theta) &= \cos \lambda \sin \delta \sin 2\theta + \frac{1}{2} \sin \lambda \sin 2\delta \cos 2\theta \\
    A_4(\lambda, \delta, \theta) &= -\cos \lambda \cos \delta \sin \theta - \sin \lambda \cos 2\delta \cos \theta \\
    A_5(\lambda, \delta, \theta) &= \cos \lambda \sin \delta \cos 2\theta - \frac{1}{2} \sin \lambda \sin 2\delta \sin 2\theta
\end{align*}
\]

where the meanings of the variables are shown in the related documents.

There are two principal steps on the linear inversion method used in this paper. First, we determine the seismic moment tensor from the data of waveform. Second, we determine the Best Double-Couple Solution from the seismic moment tensor.

1. The inversion of seismic moment tensor

On pure shear fault, shown in Figure 1, we introduce definition of Cartesian coordinates \((x, y, z)\), \(x\)-axis is North, \(y\)-axis is east and \(z\)-axis is vertically downward. We take the coordinate system on the foot wall of the fault. Slip \(u\) is taken as the direction of the hanging wall relative to the foot wall, \(n\) is normal to the fault surface of the foot wall, \(\phi\) is the strike of fault \((0^\circ \leq \phi \leq 360^\circ)\), \(\delta\) is the dip of the fault \((0^\circ \leq \delta \leq 90^\circ)\), rake \(\lambda\) is the angle between