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ORIGINAL ARTICLE

Rotation and strain seismology

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Abstract Asymmetric continuum theory points to the equal roles of the rotation motions and those related directly to shear or confining strains. The strain motions could be quite independent or mutually related with the eventual phase shifts, while the displacements have only a mathematical sense; a real displacement may appear along the fracture slip only. Formally, any deformation could be presented as related to the displacements; however, its origin in a fracture source should be considered either as belonging to an individual process or to complex correlated events; in these cases, the confining, shear and rotation strains can be related mathematically to the different displacement fields. Some of these related deformations could be emitted from a source with a phase shift, while the observed displacements (deduced from records) result as a sum of these independent displacements. An important influence on a source process and on the premonitory micro-events has the material defects, their distribution, and mobility. The defect arrays lead to a concentration of stresses and their local reorganization. Thus, in this paper, we consider the induced stresses and strains related to defect content and to its modification and redistribution. Moreover, an important role in understanding the complex correlated events in a source plays the release–rebound mechanism. The release–rebound mechanism in an earthquake source processes leads to a possible direct or phase-shifted correlations between the emitted motions; in this aspect, a propagation of the coupled strain and rotation waves is discussed. In particular, we consider the point fracture events as related either to a confining load or/and to the shear and rotation processes; we discuss the related effects and their meaning when discussing the fault plane mechanism and emitted waves. In some important seismic regions, we have the recording system which permits to record the strains and rotations. However, we should point that the word-wide seismological network is not adequate to record the complex strain deformations released in the fracture processes and remains quite insufficient to understand the global stress changes and related strain waves of a very low period. Consideration on a recording mechanism of the long displacement waves indicates the insufficiencies of the present global recording system and points that recording of the global strain and rotation waves is an important and urgent task.

Keywords Asymmetric stresses · Defect densities · Induced stresses · Recording systems

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1 Introduction

We follow the asymmetric continuum theory (Teisseyre and Górski 2008, 2009a, b, 2011) in which the postulate of the *central symmetry* (cf. Nowacki 1986) can be neglected (displacements and point rotations are treated here as only mathematical fields), analogically the opposite postulate of the *stable position* (see Eq. 5 and further on). Our theory is based solely on the independent deformations which follow from the motion relations deduced from the derivatives of the Newton equation. Accordingly these deformations, $D_{ik} = \frac{\partial u_k}{\partial x_i}$ can be separated in three independent fields: confining strain, $\overline{E} = \frac{1}{3}\sum \frac{\partial \overline{u}_k}{\partial x_k}$, shear strain, $\widehat{E}_{(ik)} = \frac{1}{2}\left(\frac{\partial \widehat{u}_k}{\partial x_i} + \frac{\partial \widehat{u}_i}{\partial x_k}\right) - \delta_{ik}\overline{E}$, and rotation strain: $E_{[ik]} \equiv \omega_{ik} = \frac{1}{2}\left(\frac{\partial \breve{u}_k}{\partial x_i} - \frac{\partial \breve{u}_i}{\partial x_k}\right)$, as related to the different reference displacements, $\overline{u}_k$, $\widehat{u}_k$, and $\breve{u}_k$. The deduced displacements from seismometer records present a sum of these motions: $u_k = \overline{u}_k + \widehat{u}_k + \breve{u}_k$; these displacements do not physically exist, these only appear due to an integration process of the recorded released strains along a fracture slip. The recorded strain waves, $\overline{E}$,$\widehat{E}_{(ik)}$, and $E_{[ik]}$, are governed by three independent motion equations (see further on).

For the strains and rotation strains, the independent balance motion relations follow from a system of the basic point motions and deformations. Traditionally, we can present any mechanical motion in a form related to displacements or displacement derivatives. However, two problems arise: first, that the different independently released deformations may be related to the different independent displacements, and second, that the correlated release processes lead to deformations which can be presented directly or with some phase shift to a certain "reference" displacement motion.

Thus, strain and rotation (rotation strain) can be presented by the adequate derivatives of some reference displacements, which could be quite different for each particular field. However, in the earthquake source processes, some strain releases may relate directly or with some phase shift ($\pm\pi/2$ or $\pm i$), to a unique reference displacement field.

Finally, we should point that many authors confess that the classical elasticity has many insufficiencies; among others; we may enumerate some of them:

- The angular motions are not incorporated in the classic theory, and even when introducing them by an artificial way, we should additionally define a position and arm of the introduced angular moment.
- The slip solutions need to be introduced with the additional friction law, not incorporated directly in the classic theory.

Numerous attempts to improve the classic theory appeared already in the beginning of the twentieth century; we should mention some of them:

- Cosserat brothers' theory with displacements and rotations (Cosserat and Cosserat 1909).
- Micropolar and micromorphic theories (Eringen 1999) bring a powerful tool for many complicated material problems; however, these seem to be too complicated because our knowledge of some material constants remains quite insufficient. Therefore, these theories are not in common use in the seismological studies (for some rare examples related to the seismological application, see Teisseyre 1973, 1974)
- Some improvements of the Cosserat continuum brought the asymmetric elasticity proposed by Nowacki (1986); however, this theory still relies on the central symmetry which assumes an independency of any rotation to a deformation response.

We should also mention some other more complicated problems, related to a continuum response due to the deformations near a critical state, considered by a number of authors (cf. Crandall et al. 1978; Feng et al. 1984, 1985; Feng 1985; Roux and Guyon 1985). More close considerations to our asymmetric theory can be found in two Russian books, Vikulin 2004; Milanovsky 2007, describing very profoundly the vortex processes in geology and physics.

The present paper continues a development of the asymmetric continuum theory (cf. Teisseyre 2009, 2011; Teisseyre and Górski 2009a, b), especially directed to the problems of the induced strains. We point also on a need of the new wordwide seismic network based on the recordings of strains and rotations.

2 Asymmetric continuum

We remind, in an abbreviated form, the main elements of the asymmetric theory, which relies on the definition of the basic motions and deformations. Our fundamental assumption states that each of these independent motions should be described by a separate motion equation.

The asymmetric strain fields, $E_{ik} = E_{(ik)} + E_{[ik]}$, can be defined as follows:

$$E_{(ik)} = \frac{1}{2}\left(\frac{\partial u_k}{\partial x_i} + \frac{\partial u_i}{\partial x_k}\right) \quad ; \qquad E_{[ik]} \equiv \omega_{ik} = \frac{1}{2}\left(\frac{\partial \breve{u}_k}{\partial x_i} - \frac{\partial \breve{u}_i}{\partial x_k}\right) \tag{1}$$

where rotational strains are defined as the antisymmetric strains and where we anticipate that the used above displacements, u and $\breve{u}$, might be either quite different for rotation, ω_{ik}, and for the symmetric strains, $E_{(ik)}$, or mutually phase shifted.

We note that, when presenting these fields as the derivatives of displacements, then the related displacements, the reference ones, have, in general, only a mathematical sense (at the lower limit of length—the Planck length, ca 10^{-35} m—these motions ω_{ik} and $E_{(ik)}$ cannot be described by any derivatives and, hence, retrieve their complete independence).

We can base our consideration on the following independent fields and motions (cf. Teisseyre and Górski 2009a, b):

- Total axial strain and stress, $\overline{E} = \frac{1}{3}\sum_s E_{ss}$, $\overline{S} = \frac{1}{3}\sum_s S_{ss}$ (pressure related);
- Axial strains and stresses, $\overline{E}_{(ss)} \equiv E_{(ss)}$, and $\overline{S}_{(ss)} \equiv S_{(ss)}$;
- Deviatoric strains and stresses, $\widehat{E}_{(ik)} = E_{(ik)} - \delta_{ik}\overline{E}$, and $\widehat{S}_{(ik)} = S_{(ik)} - \delta_{ik}\overline{S}$;
- Rotation strains and stresses (angular moment related), $\omega_{kl} = \breve{E}_{[kl]}$, $\breve{S}_{[kl]}$

These fields could be presented by derivatives of some displacements, written either as u_s or by some other symbols, e.g., $\overline{u}_s, \widehat{u}_s, \breve{u}_s$, introduced in a mathematical way to express the different strains, being either independently released in a fracture source or mutually related, possible with some phase shifts, due to a common fracture process.

We may also use the rotation vector, $\omega_s = \frac{1}{2}\varepsilon_{sik}\omega_{ik}$; where ε_{sik} is the fully antisymmetric tensor.

For the total stresses and strains, we can write:

$$\begin{aligned} S_{kl} &= S_{(kl)} + S_{[kl]} = \delta_{kl}\overline{S} + \widehat{S}_{(kl)} + \breve{S}_{[kl]} \quad ; \quad \overline{S} = \tfrac{1}{3}\sum_{s=1}^{3} S_{(ss)} \\ E_{kl} &= E_{(kl)} + \omega_{kl} = \delta_{kl}\overline{E} + \widehat{E}_{(kl)} + \breve{E}_{[kl]} \quad ; \quad \overline{E} = \tfrac{1}{3}\sum_{s=1}^{3} E_{(ss)} \end{aligned} \tag{2}$$

and we may assume for these fields the simple constitutive laws:

$$\begin{aligned} &S_{(ik)} = 2\mu E_{(ik)} + \lambda\delta_{ik}E_{(ss)} \\ &\breve{S}_{[ik]} = 2\mu\breve{E}_{[ik]} \; ; \quad \overline{S} = (2\mu + 3\lambda)\overline{E} \end{aligned} \tag{3}$$

where the independent constitutive relations for the antisymmetric fields are introduced, but for a compatibility, we have used here the same constant, μ, as for the symmetric fields; however, in general, these constants might differ (cf. Shimbo 1975, 1995).

All deformations appear due to specific load conditions, related to stress load and external rotation moment, and we postulate that to all these fields shall belong to the independent balance relations and that these fields might be either independently released in the source processes, or directly correlated, eventually with some phase shifts.

Of course, any motion and deformation can be expressed by some displacement field; to be called as the reference displacements. In general, each of the mentioned fields should be expressed by the different reference displacements. However, due the source rebound–release mechanism, some of these deformations could be expressed by the same reference displacements or those shifted in phase by ±π/2.

We can present the following relations between these deformations and the specific reference motions:

- Total axial strain

$$\overline{E} = \frac{1}{3}\sum_s E_{ss} = \frac{1}{3}\sum_s \frac{\partial \overline{u}_s}{\partial x_s} \tag{4a}$$

- Axial strains

$$\overline{E}_{(ss)} = E_{(ss)} \quad ; \quad \overline{E}_{(ss)} = \frac{\partial \overline{u}_s}{\partial x_s} \tag{4b}$$

– Rotation strains

$$\omega_{ik} \equiv \breve{E}_{[ik]} = \frac{1}{2}\left(\frac{\partial \breve{u}_k}{\partial x_i} - \frac{\partial \breve{u}_i}{\partial x_k}\right) \quad (4c)$$

– Deviatoric strains, $\widehat{E}_{(ik)}$:

$$\widehat{E}_{(ik)} = E_{(ik)} - \delta_{ik}\overline{E} = \frac{1}{2}\left(\frac{\partial \widehat{u}_k}{\partial x_i} + \frac{\partial \widehat{u}_i}{\partial x_k}\right) - \delta_{ik}\frac{1}{3}\sum_{s=1}^{3}\frac{\partial \overline{u}_s}{\partial x_s} \quad (4d)$$

From the nine components of deformations, $D_{ni} = \frac{\partial u_i}{\partial x_n}$, we can separate three independent fields: $\overline{E}$, $\widehat{E}_{(ik)} = E_{(ik)} - \delta_{ik}\overline{E}$, $\breve{E}_{[ik]}$.

Considering the emitted waves from a source, we may consider the following possible interrelations between the written reference motions, as the quite independent or correlated displacements:

$$\overline{u}_s = \xi^0 u_s, \quad \hat{u}_s = e^0 u_s, \quad \breve{u}_s = \chi^0 u_s \quad ; \quad \left\{\xi^0, e^0, \chi^0\right\} = \{0, \pm 1, \pm i\}. \quad (5)$$

For $\chi^0 = 0$ and $\xi^0 = e^0 = 1$, we return to classic elasticity, while for $\chi^0 = 1$ and $\xi^0 = e^0 = 0$, we would have a continuum with the rigid, densely packed spheres. In a first case, classic theory, the postulate of the central symmetry (cf. Nowacki 1986) means that an inversion of the coordinate system should not change any obtained solutions; this postulate eliminates only a point rotation and a strain rotation remains invariant.

For a second case (rigid spheres), we might postulate the stable position meaning that a displacement cannot change any obtained solution (in that case, the slip shifts related to fracture processes will be eliminated as well). In the asymmetric continuum theory, we reject these two extreme postulates. The introduced phase constants mean the phase delays of the considered released fields at a source; these constants do not influence the independent motions, including the rotation motions, $\breve{E}_{[ik]}$, as these fields are described by the independent relations; the related displacement motions mean only some reference fields in a mathematical sense, but physically do not exist.

The related equations of motion follow from the derivatives of the classic motion formula:

$$\mu\sum_s \frac{\partial^2 u_i}{\partial x_s \partial x_s} - \rho\frac{\partial^2 u_i}{\partial t^2} + (\lambda+\mu)\sum_s \frac{\partial^2 u_s}{\partial x_i \partial x_s} = 0 \text{ and for } D_{ni} = \frac{\partial u_i}{\partial x_n}: \quad \mu\sum_s \frac{\partial^2 D_{ni}}{\partial x_s \partial x_s} - \rho\frac{\partial^2}{\partial t^2}D_{ni} + (\lambda+\mu)\frac{\partial^2}{\partial x_n \partial x_i}\sum_s D_{ss} = 0. \quad (6)$$

From this relation, we obtain for $E_{(ni)} = \frac{1}{2}(D_{ni} + D_{in})$:

$$(\lambda+2\mu)\sum_s \frac{\partial^2 \overline{E}}{\partial x_s \partial x_s} - \rho\frac{\partial^2 \overline{E}}{\partial t^2} = 0\ ;\ \overline{E} = \frac{1}{3}\sum_s \frac{\partial^2 \overline{u}_s}{\partial x_s}, \quad \widehat{E}_{(nl)} = E_{(nl)} - \delta_{nl}\overline{E}$$
$$\mu\sum_s \frac{\partial^2 \widehat{E}_{(nl)}}{\partial x_s \partial x_s} - \rho\frac{\partial^2 \widehat{E}_{(nl)}}{\partial t^2} = -(\lambda+\mu)\left(3\frac{\partial^2 \overline{E}}{\partial x_n \partial x_l} - \delta_{nl}\sum_s \frac{\partial^2 \overline{E}}{\partial x_s \partial x_s}\right) \quad (7a)$$

and for $\widehat{E}_{(nn)} = \left\{\widehat{E}_{(11)}, \widehat{E}_{(22)}, \widehat{E}_{(33)}\right\}$ at $\sum_n \widehat{E}_{(nn)} = 0$:

$$\mu\sum_s \frac{\partial^2 \widehat{E}_{(nn)}}{\partial x_s \partial x_s} - \rho\frac{\partial^2 \widehat{E}_{(nn)}}{\partial t^2} = -(\lambda+\mu)\left(3\frac{\partial^2 \overline{E}}{\partial x_n \partial x_n} - \delta_{nn}\sum_s \frac{\partial^2 \overline{E}}{\partial x_s \partial x_s}\right) \quad (7b)$$

and for rotation strains, $\breve{E}_{[ni]} = \omega_{ni} = \frac{1}{2}(D_{ni} - D_{in})$, again we obtain a wave equation:

$$\mu\sum_s \frac{\partial^2}{\partial x_s \partial x_s}\breve{E}_{[ni]} - \rho\frac{\partial^2}{\partial t^2}\breve{E}_{[ni]} = 0 \quad (8)$$

In case of a constant pressure term, $\sum_s E_{ss}$, the Eq. 7a for the deviatoric shear strains also takes the pure wave form.

In these relations for the total, shear, and rotation strains, we have neglected the external forces (cf. Eqs. 7a and 7b) and external moment of forces (cf. Eq. 8).

These motion equations complete the basic motion relations of the asymmetric theory, including that for a rotation strains presented in a frame-indifferent form.

We should mention that to the basic independent motions, displacements, and strains (axial, shear, and rotational), we might include also a point rotation (Teisseyre and Górski 2008, 2009a, b); however, in solids, the displacements may exist, in a physical sense, only as a transport along a fracture plane and the point rotation vector, which essentially differs from strain rotation, should be neglected; a point rotation does not represent a physical field. An important experimental support of our asymmetric theory comes from the studies by Gomberg and Agne (1996) on an appearance of the angular strain components in all the studied records as obtained from the system of the strain meters; according to the classic theory, these components should not exist; however, these components appear in the asymmetric theory (Teisseyre 2011). The asymmetric strains and defect distribution play also an important role in the formation of the induced strains.

3 Defect densities and induced stresses

Strains and defect densities distributed in the arrays, which may grow successively leading to a fracture; a single fracture episode could be defined as a mutual annihilation process of the oppositely oriented defects, e.g., annihilation of the opposite dislocations or annihilation of the opposite ends of two cracks (joining of two cracks) (cf. Droste and Teisseyre 1959).

Fundamental approach to theory of a continuum distribution of defects is due to works of Kossecka and DeWitt (cf. Kossecka and DeWitt 1977); later adopted to the asymmetric theory (cf. Teisseyre 2001, 2002; Boratynski and Teisseyre 2006). We should mention also a more advanced theory of continuum distribution of defects in the micropolar media (Zubov 2011).

The induced stresses and strains appear due to defect content in a continuum; we should remember the Peach–Koehler forces exerted on defects (Peach and Koehler 1950), as appearing due to the applied stresses, S_{sk}:

$$F_n = \varepsilon_{nsq} \sum_k S_{sk} b_k \nu_q \tag{9}$$

where $\boldsymbol{b}$ is a dislocation slip vector and $\boldsymbol{\nu}$ is a dislocation line versor.

However, we may generalize the original Peach–Koehler expression assuming, first, that the stresses, S_{sk}, represent an asymmetric field and, second, that we can describe the defect content by a continuous field, $\alpha_{qk} = \nu_q b_k$; then, we define the induced stresses:

$$\begin{aligned}
&\alpha_{qk} = \nu_q b_k \quad \text{and} \\
&S_{np}^{Ind} = S_{(np)} + S_{[np]} = F_n n_p = \varepsilon_{nsq} \sum_k \alpha_{qk} S_{sk} n_p \\
&S_{(np)} = \tfrac{1}{2}\varepsilon_{nsq} \sum_k \alpha_{qk} S_{sk} n_p + \tfrac{1}{2}\varepsilon_{psq} \sum_k \alpha_{qk} S_{sk} n_n \\
&S_{[np]} = \tfrac{1}{2}\varepsilon_{nsq} \sum_k \alpha_{qk} S_{sk} n_p - \tfrac{1}{2}\varepsilon_{psq} \sum_k \alpha_{qk} S_{sk} n_n
\end{aligned} \tag{10a}$$

or

$$\begin{aligned}
S_{1p}^{Ind} &= 3(\alpha_{31}S_{21} - \alpha_{21}S_{31} + \alpha_{33}S_{23} - \alpha_{22}S_{32} + \alpha_{32}S_{22} - \alpha_{23}S_{33})n_p \\
S_{2p}^{Ind} &= 3(\alpha_{12}S_{32} - \alpha_{32}S_{12} + \alpha_{11}S_{31} - \alpha_{33}S_{13} + \alpha_{13}S_{33} - \alpha_{31}S_{11})n_p \\
S_{3p}^{Ind} &= 3(\alpha_{23}S_{13} - \alpha_{13}S_{23} + \alpha_{22}S_{12} - \alpha_{11}S_{21} + \alpha_{21}S_{11} - \alpha_{12}S_{22})n_p
\end{aligned} \tag{10b}$$

where n is a normal to defect plane.

Of course the total stresses would present the reorganized stress system due to a defect influence, as a sum of the applied stresses and induced ones:

$$S_{np}^{T} = S_{np} + S_{np}^{Ind} = S_{(np)} + S_{[np]} + S_{(np)}^{Ind} + S_{[np]}^{Ind}. \tag{11}$$

The presented wave equations (Eqs. 7a, 7b, and 8) remain valid also for a continuum with the defect density fields; effect motion velocities are evidently smaller than wave velocities, hence we may consider the defect interactions in a static approximation; however, when introducing the total stresses to these motion relations, we should modify somewhat the material constants for a better physical compatibility. In our approach, we have modified the Peach–Koehler forces including also the nonsymmetric stresses.

4 Two simple earthquake source models

We like to consider a source model a horizontal plane, $z=0$, using the (x_1, x_2, x_3) and (r,φ,z) systems as an appearance of a plane fracture event.

First, we limit our consideration to the applied confining load, S_{11}, S_{22}, and S_{33} = const. (or S_{rr}, $S_{\varphi\varphi}$, and S_{zz} = const.), and to the shear and rotation asymmetric components: S_{12}(or $S_{r\varphi}$).

For these applied stresses we will obtain, after Eq. 10b, the following induced stresses in the

(x_1, x_2, x_3) and (r,φ,z) systems due to the applied loads:

$$\begin{aligned} S_{1p}^{Ind} &= 3(\alpha_{31}S_{21} + \alpha_{32}S_{22} - \alpha_{23}S_{33})n_p \\ S_{2p}^{Ind} &= 3(\alpha_{13}S_{33} - \alpha_{32}S_{12} - \alpha_{31}S_{11})n_p \\ S_{3p}^{Ind} &= 3(\alpha_{22}S_{12} - \alpha_{11}S_{21} + \alpha_{21}S_{11} - \alpha_{12}S_{22})n_p \end{aligned} \tag{12a}$$

$$\begin{aligned} S_{rp}^{Ind} &= 3\left(\alpha_{zr}S_{\varphi r} + \alpha_{z\varphi}S_{\varphi\varphi} - \alpha_{\varphi z}S_{zz}\right)n_p \\ S_{\varphi p}^{Ind} &= 3\left(\alpha_{rz}S_{zz} - \alpha_{z\varphi}S_{r\varphi} - \alpha_{zr}S_{rr}\right)n_p \\ S_{zp}^{Ind} &= 3\left(\alpha_{\varphi\varphi}S_{r\varphi} - \alpha_{rr}S_{\varphi r} + \alpha_{\varphi r}S_{rr} - \alpha_{r\varphi}S_{\varphi\varphi}\right)n_p. \end{aligned} \tag{12b}$$

We will consider to the following specific cases:

– For the total axial loads, $S_{11}=S_{22}=S_{33}=\overline{S}$, $(S_{rr}=S_{\varphi\varphi}=S_{zz}=\overline{S})$, and for $S_{12}=S_{21}=0$ $(S_{r\varphi}=S_{\varphi r}=0)$, we obtain:

$$\begin{aligned} S_{kp}^{Ind} &= -3\varepsilon_{kns}\alpha_{ns}\overline{S}n_p: \\ S_{(kp)}^{Ind} &= -\frac{3}{2}\overline{S}\left(\varepsilon_{kns}\alpha_{ns}n_p + \varepsilon_{pns}\alpha_{ns}n_k\right), \\ S_{[kp]}^{Ind} &= -\frac{3}{2}\overline{S}\left(\varepsilon_{kns}\alpha_{ns}n_p - \varepsilon_{pns}\alpha_{ns}n_k\right) \end{aligned} \tag{13}$$

– For the loads $S_{11}, S_{22}, (S_{rr}, S_{\varphi\varphi})$, $S_{33}=S_{zz}=\overline{S}$, and $S_{12}=S_{21}=0$, $(S_{r\varphi}=S_{\varphi r}=0)$, we obtain the following total stresses, $S_{np}^T = S_{np} + S_{np}^{Ind}$, (cf. Eq. 11):

$$\begin{aligned} &S_{11}^T = S_{11} + 3\left(\alpha_{32}S_{22} - \alpha_{23}\overline{S}\right)n_1;\ \text{and for } n_p = \{n_2, n_3\}: \quad S_{1p}^T = 3\left(\alpha_{32}S_{22} - \alpha_{23}\overline{S}\right)n_p \\ &S_{22}^T = S_{22} + 3\left(\alpha_{13}\overline{S} - \alpha_{31}S_{11}\right)n_2;\ \text{and for } n_p = \{n_3, n_1\}: \quad S_{1p}^T = 3\left(\alpha_{32}S_{22} - \alpha_{23}\overline{S}\right)n_p \\ &S_{33}^T = S_{33} + 3(\alpha_{21}S_{11} - \alpha_{12}S_{22})n_3;\ \text{and for } n_p = \{n_1, n_2\}: \quad S_{1p}^T = 3\left(\alpha_{32}S_{22} - \alpha_{23}\overline{S}\right)n_p \\ &\text{and} \\ &S_{rr}^T = S_{rr} + 3\left(\alpha_{z\varphi}S_{\varphi\varphi} - \alpha_{\varphi z}\overline{S}\right)n_r;\ \text{for } n_p = \{n_\varphi, n_z\}: \quad S_{rp}^T = 3\left(\alpha_{z\varphi}S_{\varphi\varphi} - \alpha_{\varphi z}\overline{S}\right)n_p \\ &S_{\varphi\varphi}^T = S_{\varphi\varphi} + 3\left(\alpha_{rz}\overline{S} - \alpha_{zr}S_{rr}\right)n_\varphi;\ \text{for } n_p = \{n_z, n_r\}: \quad S_{\varphi p}^T = 3\left(\alpha_{rz}\overline{S} - \alpha_{zr}S_{rr}\right)n_p \\ &S_{zz}^T = S_{zz} + 3\left(\alpha_{\varphi r}S_{rr} - \alpha_{r\varphi}S_{\varphi\varphi}\right)n_z;\ \text{for } n_p = \{n_r, n_\varphi\}: \quad S_{zp}^T = 3\left(\alpha_{\varphi r}S_{rr} - \alpha_{r\varphi}S_{\varphi\varphi}\right)n_p. \end{aligned} \tag{14a}$$

We find that for the total axial loads, even beneath the value of the corresponding strength, the shear and fragmentation fracture processes can appear due to an influence of the defect coaction; however, in this case, the obtained moment tensor solutions will not fit to the applied axial load.

For the loads S_{12}, S_{21} $(S_{r\varphi}, S_{\varphi r})$, and for $S_{11}=S_{22}=S_{33}=S_{rr}=S_{\varphi\varphi}=S_{zz}=\overline{S}$, we obtain for the total stresses (cf. Eqs. 10a, 10b, and 11):

$$\begin{aligned} S_{1p}^T &= S_{1p} + 3\left(\alpha_{31}S_{21} + \alpha_{32}\overline{S} - \alpha_{23}\overline{S}\right)n_p \\ S_{2p}^T &= S_{2p} + 3\left(\alpha_{13}\overline{S} - \alpha_{32}S_{12} - \alpha_{31}\overline{S}\right)n_p \\ S_{3p}^T &= S_{3p} + 3\left(\alpha_{22}S_{12} - \alpha_{11}S_{21} + \alpha_{21}\overline{S} - \alpha_{12}\overline{S}\right)n_p \\ &\text{and} \\ S_{rp}^T &= S_{rp} + 3\left(\alpha_{zr}S_{\varphi r} + \alpha_{z\varphi}\overline{S} - \alpha_{\varphi z}\overline{S}\right)n_p \\ S_{\varphi p}^T &= S_{\varphi p} + 3\left(\alpha_{rz}\overline{S} - \alpha_{z\varphi}S_{r\varphi} - \alpha_{zr}\overline{S}\right)n_p \\ S_{zp}^T &= S_{zp} + 3\left(\alpha_{\varphi\varphi}S_{r\varphi} - \alpha_{rr}S_{\varphi r} + \alpha_{\varphi r}\overline{S} - \alpha_{r\varphi}\overline{S}\right)n_p. \end{aligned} \tag{14b}$$

In the above relations, we might assume that the constant axial load before an event may exhibit some stress drop after it.

The considered total stresses may be separated to the symmetric and antisymmetric parts; as an example, we may write the Eq. 14b, omitting for a simplicity total axial stresses, $\overline{S}$:

$$\begin{aligned} &S_{12}^T \approx S_{12} + 3\alpha_{31}S_{21} = (S_{(12)} + 3\alpha_{31}S_{(12)})_{\text{shear}} \\ &\quad + (S_{[12]} - 3\alpha_{31}S_{[12]})_{\text{rotation}} S_{21}^T \approx S_{21} - 3\alpha_{32}S_{12} \\ &\quad = \left(S_{(12)} - 3\alpha_{32}S_{(12)}\right)_{\text{shear}} - \left(S_{[12]} + 3\alpha_{32}S_{[12]}\right)_{\text{rotation}} \\ &\text{and} \\ &S_{r\varphi}^T \approx S_{r\varphi} + 3\alpha_{zr}S_{\varphi r}^{Ind} = \left(S_{(r\varphi)} + 3\alpha_{zr}S_{(r\varphi)}^{Ind}\right)_{\text{shear}} \\ &\quad + \left(S_{[r\varphi]} - 3\alpha_{zr}S_{[r\varphi]}^{Ind}\right)_{\text{rotation}} S_{\varphi r}^T \approx S_{\varphi r} - 3\alpha_{z\varphi}S_{r\varphi}^{Ind} \\ &\quad = \left(S_{(\varphi r)} - 3\alpha_{z\varphi}S_{(r\varphi)}^{Ind}\right)_{\text{shear}} - \left(S_{[r\varphi]} + 3\alpha_{z\varphi}S_{[r\varphi]}^{Ind}\right)_{\text{rotation}} \end{aligned} \tag{15}$$

Separately, we can consider another case with the external loads: S_{13} (S_{rz}), then, similarly to Eq. 15, the total fields acting in a source would become:

$$\begin{aligned} S^T_{13} &= \left(S_{(13)} - 3\alpha_{21}S_{(31)}\right)_{\text{shear}} \\ &\quad + \left(S_{[13]} - 3\alpha_{21}S_{[31]}\right)_{\text{rotation}} \\ S^T_{31} &= \left(S_{31} + 3\alpha_{23}S_{(13)}\right)_{\text{shear}} \\ &\quad + \left(S_{[31]} - 3\alpha_{23}S_{[31]}\right)_{\text{rotation}} \quad \text{and} \\ S^T_{rz} &= \left(S_{(rz)} + 3\alpha_{zr}S_{(\varphi r)}\right)_{\text{shear}} \\ &\quad - \left(S_{[rz]} + 3\alpha_{zr}S_{[r\varphi]}\right)_{\text{rotation}} \\ S^T_{zr} &= \left(S_{(\varphi r)} + 3\alpha_{\varphi\varphi}S_{(r\varphi)} - 3\alpha_{rr}S_{(\varphi r)}\right)_{\text{shear}} \\ &\quad - \left(S_{[r\varphi]} - 3\left(\alpha_{\varphi\varphi} + \alpha_{rr}\right)S_{[r\varphi]}\right)_{\text{rotation}}. \end{aligned} \tag{16}$$

We conclude that an influence of the defect fields will effectively accelerate also the fracture processes for shear and angular moment loads; in these last cases (cf. Eqs. 15 and 16), the obtained moment tensor solutions will fit well to the applied loads.

However, as mentioned before, we should note that the emitted strain fields due to some event, or micro-event, could be quite accidental for the axial load (cf. Eq. 14a), while for the complex load (Eq. 14b), some parts of the observed moment tensor solution (fault plane solutions) could deviate from the applied shear or moment loads in the different manner at different recording sites; probably it would be possible to select true solutions when using data from the several recording sites.

We should remember that for the shear and rotation processes, $\widehat{E}$ and $\breve{E}$, we might observe the strain drops and the related waves appearing with the $\pi/2$ phase shift between these fields.

Let us return, again, to an action of the pure confining stresses; when the load $\overline{S} = \frac{1}{3}\sum_k S_{kk}$ (cf. Eq. 2) increases slowly, we might observe an appearance of the more and more defects and related induced stresses; the material properties undergo changes. To explain more clearly a role of defect content on the formation of the induced stresses under confining load, we may use some simplifications by imagining two artificial states: first, "purely elastic" related to the increasing stresses and strains in a domain up to the upper limit of the "pure elasticity" for some artificial limits $E_{nl} \leq E^{\text{Max}}_{nl}$:

$$\sum_k S_{kk} = (3\lambda + 2\mu)\sum_k E_{kk} \text{ and } S_{nl} = \lambda\delta_{nl}\sum_k E_{kk} + 2\mu E_{nl} \tag{17}$$

and another related to higher stresses and strains, $E^{\text{Max}}_{nl} \leq E_{nl} \leq E^{\text{Fracture}}_{nl}$, up to a fracture level at which an increase of confining load causes the defect increase (including organization of defect arrays) (cf. Eq. 13):

$$S^{Ind}_{np} = -3\varepsilon_{nms}\alpha_{ms}\overline{S}n_p = -6\mu\varepsilon_{nms}\alpha_{ms}\overline{E}n_p; n \neq p \tag{18}$$

where, for simplicity, we might use here the same material constant, μ

Such artificial division permits to better understand a role of defects in a progressive approach to fracture (or micro-fracture) under a confining load; in real processes, these two artificial states are combined with decreasing role of the first "elastic" state and increasing significance of a counterpart of defects in a way to fracture. The defect influence increases slowly at low stress load and quite rapidly in a final stage close to fracture processes (we might also include the changes of the material properties and appearance of some material anisotropy). From Eq. 18, it follows that in a final fracture process (under confining load), the shear and rotation stress release should be expected when these stresses will approach to the respective strength level. This state can be achieved due to an increase of applied load and quite quick rise of a role of the defects. Thus, we repeat that when approaching to fracture process, the pressure-related strength remains still to high to allow related fracture, but a high increase of defect content and due to much lower strength for shear or fragmentation processes (rotational concentric fractures), we will arrive at a fracture event related to the shear and rotational processes:

$$\begin{aligned} S^{Ind}_{np} &= \widehat{S}^{Ind}_{(np)} + \breve{S}^{Ind}_{[np]} = -3\varepsilon_{nms}\alpha_{ms}\overline{S}n_p \\ &\approx \widehat{S}^{\text{Strength}}_{(np)} + \breve{S}^{\text{Strength}}_{[np]}; n \neq p. \end{aligned} \tag{19}$$

These fracture events relate to shear and fragmentation fractures and the related wave radiation will relate to the $\widehat{E}^{Ind}_{(np)}$ and $\breve{E}^{Ind}_{[np]}$ fields, it means that not to the axial load.

Thus, we should be aware that the observed fault plane solutions will not relate directly to the axial load condition but to the shear and fragmentation processes of the different orientations (see Fig.1).

For the processes under confining load, this statement raises a very important remark. However, we should mention that a different situation will be for the shear and rotation moment loads.

In the (r,θ,φ) system, we obtain the following from the Eqs. 10a, 10b, and 11:

$$\begin{aligned}
S^T_{rp} &= S_{rp} + 3\left(\alpha_{\varphi r}S_{\theta r} - \alpha_{\theta r}S_{\varphi r} + \alpha_{\varphi\varphi}S_{\theta\varphi} - \alpha_{\theta\theta}S_{\varphi\theta} + \alpha_{\varphi\theta}S_{\theta\theta} - \alpha_{\theta\varphi}S_{\varphi\varphi}\right)n_p \\
S^T_{\theta p} &= S_{\theta p} + 3\left(\alpha_{r\theta}S_{\phi\theta} - \alpha_{\varphi\theta}S_{r\theta} + \alpha_{rr}S_{\varphi r} - \alpha_{\varphi\varphi}S_{r\varphi} + \alpha_{r\varphi}S_{\varphi\varphi} - \alpha_{\varphi r}S_{rr}\right)n_p \\
S^T_{\varphi p} &= S_{\varphi p} + 3\left(\alpha_{\theta\varphi}S_{r\varphi} - \alpha_{r\varphi}S_{\theta\varphi} + \alpha_{\theta\theta}S_{r\theta} - \alpha_{rr}S_{\theta r} + \alpha_{\theta r}S_{rr} - \alpha_{r\theta}S_{\theta\theta}\right)n_p
\end{aligned} \tag{20a}$$

and for the shear and rotation stresses separately:

$$\begin{aligned}
\begin{Bmatrix} S^T_{(r\theta)} \\ S^T_{[r\theta]} \end{Bmatrix} &= \begin{Bmatrix} S_{(r\theta)} \\ S_{[r\theta]} \end{Bmatrix} + \frac{3}{2}\left(\alpha_{\varphi r}S_{\theta r} - \alpha_{\theta r}S_{\varphi r} + \alpha_{\varphi\varphi}S_{\theta\varphi} - \alpha_{\theta\theta}S_{\varphi\theta} + \alpha_{\varphi\theta}S_{\theta\theta} - \alpha_{\theta\varphi}S_{\varphi\varphi}\right)n_\theta \pm \\
&\quad \frac{3}{2}\left(\alpha_{r\theta}S_{\varphi\theta} - \alpha_{\varphi\theta}S_{r\theta} + \alpha_{rr}S_{\varphi r} - \alpha_{\varphi\varphi}S_{r\varphi} + \alpha_{r\varphi}S_{\varphi\varphi} - \alpha_{\varphi r}S_{rr}\right)n_r \\
\begin{Bmatrix} S^T_{(r\varphi)} \\ S^T_{[r\varphi]} \end{Bmatrix} &= \begin{Bmatrix} S_{(r\varphi)} \\ S_{[r\varphi]} \end{Bmatrix} + \frac{3}{2}\left(\alpha_{\varphi r}S_{\theta r} - \alpha_{\theta r}S_{\varphi r} + \alpha_{\varphi\varphi}S_{\theta\varphi} - \alpha_{\theta\theta}S_{\varphi\theta} + \alpha_{\varphi\theta}S_{\theta\theta} - \alpha_{\theta\varphi}S_{\varphi\varphi}\right)n_\varphi \pm \\
&\quad \frac{3}{2}\left(\alpha_{\theta\varphi}S_{r\varphi} - \alpha_{r\varphi}S_{\theta\varphi} + \alpha_{\theta\theta}S_{r\theta} - \alpha_{rr}S_{\theta r} + \alpha_{\theta r}S_{rr} - \alpha_{r\theta}S_{\theta\theta}\right)n_r \\
\begin{Bmatrix} S^T_{(\theta\phi)} \\ S^T_{[\theta\varphi]} \end{Bmatrix} &= \begin{Bmatrix} S_{(\theta\varphi)} \\ S_{[\theta\varphi]} \end{Bmatrix} + \frac{3}{2}\left(\alpha_{r\theta}S_{\varphi\theta} - \alpha_{\varphi\theta}S_{r\theta} + \alpha_{rr}S_{\varphi r} - \alpha_{\varphi\varphi}S_{r\varphi} + \alpha_{r\varphi}S_{\varphi\varphi} - \alpha_{\varphi r}S_{rr}\right)n_\varphi \pm \\
&\quad \frac{3}{2}\left(\alpha_{\theta\varphi}S_{r\varphi} - \alpha_{r\varphi}S_{\theta\varphi} + \alpha_{\theta\theta}S_{r\theta} - \alpha_{rr}S_{\theta r} + \alpha_{\theta r}S_{rr} - \alpha_{r\theta}S_{\theta\theta}\right)n_\theta.
\end{aligned} \tag{20b}$$

We should note a counterpart of the angular-squeeze stress component, $S_{\varphi\varphi}$, and the related defects, $\alpha_{\varphi\varphi}$, on formation of the induced and total strains and the related breaks (Teisseyre 2011).

As a particular case, we will consider the confining load condition, $\overline{S} = S_{rr} = S_{\theta\theta} = S_{\varphi\varphi}$, that may lead to some fracture event at the origin of the used coordinate system:

$$\begin{aligned}
S^T_{rp} &= 3\overline{S}\left(\alpha_{\varphi\theta} - \alpha_{\theta\varphi}\right)n_p; n_p = \{n_\theta, n_\varphi\} : \\
S^T_{\theta p} &= 3\overline{S}\left(\alpha_{r\varphi} - \alpha_{\varphi r}\right)n_p; n_p = \{n_\varphi, n_r\} : \\
S^T_{\varphi p} &= 3\overline{S}(\alpha_{\theta r} - \alpha_{r\theta})n_p; n_p = \{n_r, n_\theta\} :.
\end{aligned} \tag{21a}$$

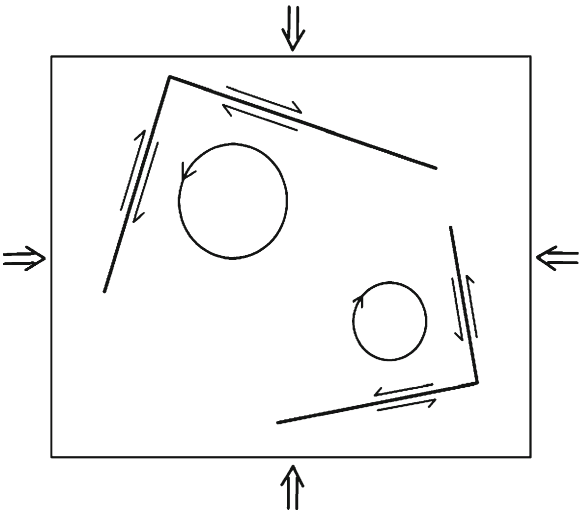

Fig.1 Shear and fragmentations of different orientations due to the confining load

Hence, for the shear and rotation stresses, we obtain (cf. Eq. 20b):

$$
\begin{aligned}
\left\{\begin{matrix} S^T_{(r\theta)} \\ S^T_{[r\theta]} \end{matrix}\right\} &= \frac{3}{2}\overline{S}\left\{\left(\alpha_{\varphi\theta}-\alpha_{\theta\varphi}\right)n_\theta \pm \left(\alpha_{r\varphi}-\alpha_{\varphi r}\right)n_r\right\} \\
\left\{\begin{matrix} S^T_{(r\varphi)} \\ S^T_{[r\varphi]} \end{matrix}\right\} &= \frac{3}{2}\overline{S}\left\{\left(\alpha_{\varphi\theta}-\alpha_{\theta\varphi}\right)n_\varphi \pm \left(\alpha_{\theta r}-\alpha_{r\theta}\right)n_r\right\} \\
\left\{\begin{matrix} S^T_{(\theta\varphi)} \\ S^T_{[\theta\varphi]} \end{matrix}\right\} &= \frac{3}{2}\overline{S}\left\{\left(\alpha_{r\varphi}-\alpha_{\varphi r}\right)n_\varphi \pm \left(\alpha_{\theta r}-\alpha_{r\theta}\right)n_\theta\right\}.
\end{aligned}
\tag{21b}
$$

Considering the strains induced only due to the edge type defect arrays, $\alpha_{\varphi r}$ (originally being formed on the perpendicular planes n_θ) and $\alpha_{\theta r}$ (originally being formed on the perpendicular planes n_φ), we obtain for the strains on the particular planes (here, total fields remain equal to the induced ones):

$$
\begin{aligned}
\left\{\begin{matrix} S^T_{(r\theta)} \\ S^T_{[r\theta]} \end{matrix}\right\} &= \mp\frac{3}{2}\overline{S}\alpha_{\varphi r}n_r, \left\{\begin{matrix} S^T_{(r\varphi)} \\ S^T_{[r\varphi]} \end{matrix}\right\} \\
&= \pm\frac{3}{2}\overline{S}\alpha_{\theta r}n_r, \left\{\begin{matrix} S^T_{(\theta\varphi)} \\ S^T_{[\theta\varphi]} \end{matrix}\right\} \\
&= \frac{3}{2}\overline{S}\left\{-\alpha_{\varphi r}n_\varphi \pm \alpha_{\theta r}n_\theta\right\}.
\end{aligned}
\tag{21c}
$$

These total stresses present only the induced parts appearing due to action of the confining load $\overline{S}$; such induced fields might be responsible for the shear and rotation fractures (fragmentations) as presented in Fig. 1. The obtained stress system (Eq. 21c) leads to some interesting correlations and mutual support of the induced strains and defect arrays. Thus, we can observe, as shown in Fig. 2 (subpanels a and b), that the defect arrays, $\alpha_{\theta r}$ (formed on the planes, n_φ and $n_{\varphi+\pi/2}$), can support a formation of the defect arrays, $\alpha_{\varphi \mathrm{r}}$ (formed on the plane n_θ). Similarly, the strains $E^T_{(r\varphi)} = E^{Ind}_{(r\varphi)}$ (or/and $E^T_{[r\varphi]} = E^{Ind}_{[r\varphi]}$), on planes, n_φ and $n_{\varphi+\pi/2}$, and strains $E^T_{(\theta\varphi)} = E^{Ind}_{(\theta\varphi)}$ (or/and $E^T_{[r\varphi]} = E^{Ind}_{[r\varphi]}$), on plane n_θ, form the mutually related deformation systems related to the defect accumulation and shear strains (or/and rotation strains), cf. Fig. 2 (as shown on this figure, the mentioned deformation systems are similar to an equivalence of the rotations along the φ and θ paths, see Fig. 2, subpanel c).

5 Release–rebound as described by a release of rotation, $\partial\breve{E}/\partial t$

Due to a fracture process, e.g., an earthquake, a wave propagation is excited. The release–rebound theory (cf. Teisseyre 1985, 2011) states that a release of one field, e.g., break of molecular bonds, causes the rebound release of another field. To write the related equations, we should define the following vector fields:

– the rotation vector $\breve{E}_i$ defined as
  $\breve{E}_i = \left\{\breve{E}_{[23]}, \breve{E}_{[31]}, \breve{E}_{[12]}\right\}$, and
– the shear vector $\widehat{E}_i = \left\{\widehat{E}_{(23)}, \widehat{E}_{(31)}, \widehat{E}_{(12)}\right\}$, which might be defined only in the off-diagonal
– coordinate system, $\widehat{E}_{(11)} = \widehat{E}_{(22)} = \widehat{E}_{(33)} = 0$; however, when using the 4D approach the vector,
– $\widehat{E}_i$ could be defined invariantly (cf. Teisseyre 2009).

These release–rebound processes fit well to the geometry of wave propagation (Teisseyre and Górski 2011) and can be described by the Maxwell-like relations (Teisseyre 2009). Thus, when considering the

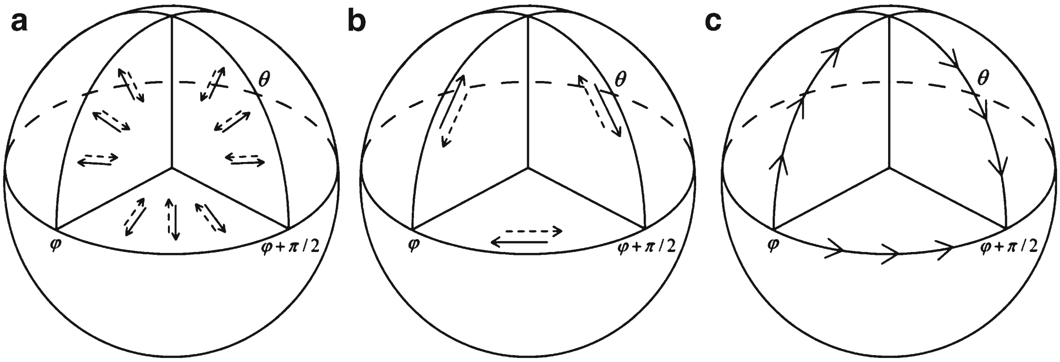

Fig. 2 Coaction processes. **a** Coaction of the induced shears. **b** Coaction of the rotation strain. **c** Coaction of the simple rotations

related vector fields, shear, and rotation strains, we may write:

$$\begin{aligned} &\operatorname{rot} \breve{E} - \frac{\partial \widehat{E}}{V^S \partial t} = 0, \\ &\operatorname{rot} \widehat{E} + \frac{\partial \breve{E}}{V^S \partial t} = 0; V^S = \sqrt{\frac{\mu}{\rho}}. \end{aligned} \tag{22}$$

Here, a release of shear field, $\partial\widehat{E}/\partial t$, causes the rebound release of a rotation (angular) strains, rot $\breve{E}$;

and vice versa a release of rotation strain, $\partial\breve{E}/\partial t$, causes the rebound release of shears, rot $\widehat{E}$.

The presented wave propagation system explains an interrelated mosaic of the shear and rotation motions (Teisseyre and Górski 2011); we may mention that in this way we can replace the mutual relations between the displacements and rotations in the Cosserat-like theories as these displacements and rotations do not physically exist as is underlined in our approach. However, we should mention that the displacements may appear along a fracture slip.

From these relations, we can derive the wave equations for rotation and shear fields, which, de facto, are mutually correlated (Eq. 22):

$$\Delta\breve{E} - \frac{\partial^2 \breve{E}}{V^2 \partial t^2} = 0 \text{ and } \Delta\widehat{E} - \frac{\partial^2 \widehat{E}}{V^2 \partial t} = 0. \tag{23}$$

6 Recordings of strains

Our considerations were related to the strain release processes, including rotation strains released in the seismic sources and to the related wave fields. To record and analyze the related processes and emitted waves, we should relay on the adequate global recording data. Thus, we should shortly note that the existing global seismic network is based on the displacement data; only in few seismically active sites the strain meters and rotation recording instruments exist. Thus, we cannot trace the global changes of the shear and rotation strains. Moreover, we should stress that the recorded displacement data refer to a total sum of the all deformation released. The true displacements relate only to the slip motions along the faults and might be observed at the near surface-situated faults.

However, the recorded displacements belong only to the displacement derivatives related to a sum of the released strains and should be treated as the reference displacements, which may be different for the different strains. We should note that it is even very difficult to imagine a release and, afterwards, also record the very long displacement waves. The related displacements do not exist, but the deformations, that is the derivatives, $\frac{\partial u_q}{\partial x_p}$, really exist.

The seismometers record the displacement derivatives: the seismometers record the integrated effect related to an appropriate interval, Δx; we notice that a recording of displacements follows due to the integration process related to deformation and leads to an artificial displacement (for a given wave period, T):

$$\begin{aligned} &\int \Delta u_k \frac{dt}{T} \approx \sum \frac{\partial u_k}{\partial x_i} \Delta x_i \frac{\Delta t_i}{T} \approx \sum \Delta u_k \frac{\Delta t}{T} \\ &\approx u_k, \text{at } \Delta u_k = \frac{\partial u_k}{\partial x_i} \Delta x_i \end{aligned} \tag{24a}$$

where Δx_i is a length of a seismometer platform much more rigid than soil layers (rigid platform). Real displacements appear along the fracture slip only.

Similarly, from the recorded strain rotations, by means of a special rotation sensor, we may reveal an artificial rotation motion, ω:

$$\int \Delta\omega \frac{dt}{T} \approx \frac{1}{2\pi} \sum_i \frac{\partial\omega}{R\partial\varphi} \frac{\Delta t_i}{T} (2\pi R)$$
$$\approx \sum_i \Delta\omega \frac{\Delta t_i}{T} \approx \omega, \text{ at } \Delta\omega = \sum_i \frac{\partial\omega}{\partial\varphi} \Delta\varphi_i. \tag{24b}$$

where $2\pi R$ means a circle related to a rotation sensor area.

We should be aware that when an earthquake event may occur in a given risk region, the amplitudes of the long strain waves would increase. We conclude that the desired global strain network should be able to trace the changes of the different strains and, in this way, we may obtain the important information on a seismic risk in different regions. Therefore, we stress that the new wordwide seismic network based on the strain and rotation recording data is extremely important.

7 Conclusions

Most of the above-presented relations remain linear; however, the material micro-destructions preceding an earthquake, and in the earthquake fracture processes, are evidently the strongly nonlinear processes. In the presented approach, we included an influence of the defect fields and formation of the induced stresses; however, basically these relations should be the nonlinear ones.

We have shown that, in a case of the confining load, a character of the fracture processes, including an appearance of the micro-fractures, may be quite different than that related to the axial load. This is caused by the internal defects and their influence on the reorganization of the applied load; the related fault plane solutions could not fit to the confining load conditions. The induced stresses disturb a search for the fault plane solutions also in other cases.

The destruction processes related to any seismic event depend not only on the boundary or initial stresses (a combination of the axial compression, deviatoric shear, and antisymmetric stresses moment related), but also on an unknown combination of the internal defect distribution with its variations, in particular due to human activity. Such an approach might include the changes of some material properties, e.g., due to a water infiltration, as caused by human activity or some natural phenomena.

In this presentation, we have introduced several new ideas and a new approach to the continuum theory; these considerations need, of course, future studies. Finally, we should recall an urgent need to create the new wordwide seismic network based on the strain recording data including rotations.

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