ROTATIONAL SEISMIC WAVES AND SOLITONS

Eugeniusz Majewski
Institute of Geophysics, Polish Academy of Sciences
ul. Ksiecia Janusza 64, 01-452 Warsaw, Poland

ABSTRACT

There is a lot of observational evidence concerning rotational motions on the Earth's surface excited by earthquakes. From observations of rotations of tombstones, chimneys, small pyramids of wooden blocks, St. Bruno obelisks, stone lanterns, vases, and many other objects on the Earth's surface, we can infer the existence of rotational motions in earthquake focal zones. Rotational motions in earthquake sources naturally generate rotational seismic waves. The goal of this presentation is to describe rotational seismic waves excited in earthquake sources.

We consider a continuum with nonlinear microstructure. Such a continuum allows the propagation of nonlinear rotational seismic waves. We consider a collinear propagation of the seismic P waves and the rotational seismic waves. As a result, we obtain a nonlinear equation describing rotational seismic waves propagating in the solid Earth modeled as the continuum with nonlinear microstructure. We found that the influence of microstructure is visible in affecting the wave velocity. The microstructure provides us with the formalism that is essential in the description of double dispersion. The derived nonlinear equation reveals the interplay between the nonlinearity and dispersion. It is noteworthy that the continuum is linear at the macroscopic level, but nonlinear at the microscopic level.

Finally, we compare the nonlinear wave equation for rotational waves with the doubly-dispersive equation. For some wavelength to grain size ratios these waves propagate as seismic solitary waves or seismic solitons. We distinguish two kinds of rotational seismic waves: (i) longitudinal rotational waves, i.e., PR waves, and (ii) shear rotational waves, i.e., SR waves. Rotational seismic waves propagate faster in solid rocks and much slower in fractured media along tectonic faults. The slow rotational tectonic waves propagate along the fractured tectonic fault with a speed of about one kilometer per day. These waves may have a form of rotational seismic solitons and they can trigger earthquakes.

We distinguish spin and twist solitons. Due to the fact that solitons can propagate without any loss of energy, these waves are extremely important carriers of seismic energy and information. Thus, the information or the message carried by rotational seismic solitons is very strong, because it starts from the earthquake source and reaches a recording station without any loss of information. It is safe to say that the rotational waves carry crucial information concerning the earthquake source processes. We can also say that the rotational waves carry information about the properties of rocks beneath the seismic station.

Now, a new challenge emerges: how can we decipher this information? The nagging question naturally arises: what are the circumstances at which the rotational seismic waves branch into rotational seismic solitons? So far, we do not have a complete and definite answer to this question. We know only that there is a critical value of the ratio of a wavelength over the grain size, in which a solution is branching from the rotational seismic wave. The problem is so complex that many factors and mechanisms can be responsible for the branching and the formation of solitons. Thus, the research on rotational seismic solitons is essential for investigating the propagation of seismic waves and helps understand mechanisms triggering earthquakes. Teisseyre and Yamashita split the stress motion equation into seismic wave and fault-related fields. We apply this method and split our equation for elastic distortion solitons into seismic soliton and fault-related soliton equations. The equation for self-distortion obtained as a result of splitting can be treated as an approximation.