Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

SSS018-P04 Room: Convention Hall Time: May 25 17:15-18:45

FDM simulation for a solid-liquid medium

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The numerical simulation such as finite-difference method (FDM) applying for large-scale region has become familiar by the progress of the computer environment. We can investigate seismic wavefields in a complex structure by solving the elastodynamic equation and the constitute equation numerically with the simulation method. In order to improve the accuracy of the simulation results, it is necessary to use the smaller scale grid and the coefficients of the higher-order finite differences. However, these processing only are not effective for the medium containing liquid, and the FDM simulation cannot explain an analytical solution correctly without satisfying the boundary condition between the solid and the liquid medium as shown by the 2D simulation case of Okamoto and Takenaka (2005). In the present study, we investigate the finite difference solution around the solid-liquid interface in order to simulate the 3D seismic wavefield with high accuracy in sea areas.
We use the 3D staggered HOT-FDM code by Nakamura et al. (2009). In this code, the structual boundary is allocated on the shear-stress component of the staggered grid and the second order precision of the finite difference is applied around the solid-liquid interface to satisfy the boundary condition between the solid and the liquid medium. We also introduce the PML layer (convolutional PML: e.g., Roden and Gedney, 2000) to avoid mixing of the reflected wave from the computational domain side. The constructed code is applied for the following three cases; 1) the interface plane allocated parallel to the horizontal plane, 2) the interface plane inclined to one direction of the Cartesian coordinate, and 3) the interface plane inclined to two directions, using the second or fourth order precision of the finite difference spatially for each case.
Our results indicate that the FDM simulation with the fourth order precision cannot explain the analytical solution such as the amplitude of body and interface waves. The results especially for the case 2) and 3), which has the interfaces to two or three directions, show the low-frequency noise in the later part of the waveform by the influence of the liquid. Our results imply that the high order finite difference may cause the numerical error and be unsuitable to apply the calculation for a complex bathymetric structure because of using another grid component stepping over the interface at the differential calculation. In the present study, we compare the results of our calculation and report the relationship between the arrangement of the interface and the accuracy of the finite difference around the interface.

Keywords: seismic wave propagation, FDM