Eigen oscillation of an elliptic fluid inclusion as a source mechanism of volcanic tremors

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Volcanic tremors and long-period events have been observed around many active volcanos in the world. These signals are considered to be generated by the motion of volcanic fluid like magma and volcanic gases, and the elucidation of these signals is one of the critical keys to understand the dynamics of the volcanic system. To explain the characteristics of these volcanic signals such as spectral peaks and/or sustaining oscillations, several models including flow-induced nonlinear oscillations of the conduit (Julian, 1994) and the resonance of fluid inclusions whose shapes are sphere (e.g., Fujita et al., 1995, 1999), cylinder/pipe (e.g., Chouet, 1985), and crack (e.g., Chouet, 1986) have been proposed and successfully applied to the analyses of observed signals. Recent studies have also demonstrated that the temporal change in the physical state of volcanic fluids can be determined from the analyses of resonant characteristics of observed signals based on these resonant models. Detailed studies on the resonance of fluid inclusions of simple geometries mentioned above may thus be an important key for the quantitative monitoring of volcanic activities. The resonance of fluid-filled cracks, however, has been studied only by numerical methods such as the finite difference method (Chouet, 1986) and the boundary integral method (Yamamoto, 2005), and the direct comparison of obtained results with the analytic eigen mode solutions for spherical and cylindrical inclusions seems to be rather difficult. In this study, to see the relationship between eigen modes for sphere and crack, I consider the resonance of elliptic fluid inclusions.

In this study, the resonance of a 2-D/3-D elliptic fluid-filled inclusion embedded in deformable surrounding medium is considered as a source model of the volcanic signals. Although eigen oscillation problems in similar situation have been already studied analytically in the engineering field (e.g., Hong and Kim, 1995), most of the previous studies assumed rigid surrounding medium, and no interaction between fluid inside the inclusion and surroundings was taken into account. In this study, I thus take into account the elastic coupling at the inclusion surface. For 2-D problem, I describe the motion inside/outside of elliptic inclusion using family of Mathieu functions with the assumptions of inviscid ideal fluid and no advection term, and determine the eigen mode by solving an algebraic equation corresponding to the boundary conditions at inclusion surface. For 3-D problem, I utilize the method of Arscott (1983) and derive semi-analytic solutions on the elliptic coordinate. Obtained eigen modes of elliptic body show clear dispersive characteristics which is one of the most remarkable features of resonance of fluid-filled crack discovered by Chouet (1986) compared with those of circular/spherical body. Such results suggest that the analytic modeling of elliptic resonant body acts as an intermediary between simple spherical model and crack model, and that the model serve as a new tool to constrain the geometry of source of volcanic signals.