The analysis of olivine viscoelastic behavior with master curve method

*Masakazu Yashiro[1], Jun Muto[1], Hiroyuki Nagahama[1]

1. TOHOKU University

1. Introduction

The viscoelastic behavior of rocks has two regimes; transient regime and steady-state regime. The transient viscoelastic behavior of rocks has been modeled by Burgers rheology (e.g. Chopra, 1997). The viscoelastic behavior of the upper-mantle during the post-seismic deformation of the 2011 Tohoku-Oki earthquake used the Burgers model (Sun et al., 2014; Muto et al., 2016). The analysis of rocks including elastic behaviors, transient and steady-state regime uniformly have not been made yet Shimamoto (1987) proposed the master curve method to model all regimes of deformation and analyzed deformation experiments of halite (Heard, 1972). Therefore in our study, we analyze the previously published results on olivine deformation experiments under high temperatures and pressure, using the master curve method. We confirm that the master curve method is an useful method analyzing viscoelastic behaviors of rocks. So, the purpose of our study is to establish the rheological model of viscoelastic behaviors of olivine including transient regime.

2. Methods

We analyzed the previously published experimental results of olivine single crystals (Demouchy et al., 2009, 2013) and aggregates (Chopra and Pateson, 1981, 1984) using the master curve method. We calculate the secant modulus and the temperature-reduced time with master curve method. The secant modulus can be obtained by the slope of a straight line between a point at a fine strain and a point at an initial condition on the stress-strain curve (Kawada et al., 2004). The temperature-reduced time indicates that temperature can be changed for deformation time. The original dataset includes several strain rate and temperature conditions. We normalized certain strain and temperature.

3. Result

The dataset of deformation experiments are experimetns of single crystals of San Carlos by Demouchy et al. (2009, 2013), Anita bay and Aheim dunite by Chopra and Paterson (1981, 1984), and synthetic aggregates using San Carlos olivine by Karato et al. (1986). The dataset of wet specimens indicated by the original paper were distinguished from dry experiments. In the experiments of Karato et al. (1986), the master curves of the same temperature conditions were made. The master curve of wet olivine was compared to that of dry olivine. The datasets of Demouchy et al. (2009, 2013) and Chopra and Paterson (1981, 1984) were arranged with the secant modulus and temperature-reduced time. Both datasets were approximated by two straight line which have different slopes. In experiments of Demouchy et al. (2009, 2013), the value of slopes are 1.0 and 0.2 on the low and high temperature-reduced time respectively. In experiments of Chopra and Paterson (1981, 1984), the values are 0.5 and 0.9.

4. Discussion

From the master curve method, the viscoelastic behavior of the dry olivine was found to have lower secant modulus in the same deformation time than that of the wet olivine. This is consistent with rheological effect of water dissolving into minerals and decreasing the strength. The analysed results of Demouchy et al. (2008, 2013) indicate that the straight line of the master curve is divided into two different slopes in different regions, indicating that deformation mechanism has changed in the each region. When the temperature-reduced time is short, the rheological behavior of single crystals can be approximated by Newtonian fluid, while when the temperature-reduced time is long, its rheological behavior follows the power-law flow. The shorter the temperature-reduced time expresses the lower temperature or higher strain rate region (Kawada and Nagahama, 2004). Therefore, in the low temperature region, the deformation behavior of olivine single crystal can be approximated to Newtonian fluid, while it follows the power-law flow in high temperature and low strain rate region. Newtonian fluid can be modeled by Maxwell model. On the other hand, it is known that a master curve which can be equal to a power-law can be approximated by a generalized Maxwell model in which Maxwell models are arranged in parallel (Kawada et al., 2006). In summary, the viscoelastic behavior of olivine single crystals carried out by Demouchy et al. (2008, 2013) can be modeled by generalized Maxwell model. In the analyzed results of Chopra and Paterson (1981, 1984), the straight line of the master curve was also divided into two different ones. When the temperature-reduced time is shorter, it follows the power-law flow, while when the temperature-reduced time is long, it can approximate the Newtonian fluid. We

Keywords: rheology

