Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS29-P12 会場:コンベンションホール 時間:5 月 24 日 18:15-19:30

JFAST コアサンプルの摩擦実験結果を用いた地震サイクルシミュレーション
Earthquake sequence simulations using measured frictional properties for JFAST core sample

野田 博之 [1*] ; 澤井 みち代 [2] ; 芝崎 文一郎 [3]
NODA, Hiroyuki[1*] ; SAWAI, Michiyo[2] ; SHIBAZAKI, Bunichiro[3]

[1] 海洋研究開発機構, [2] 広島大学, [3] 建築研究所
[1]JAMSTEC, [2]Hiroshima University, [3]Building Research Institute

Parameters in a rate- and state-dependent friction law (RSF) are often determined by velocity-step tests in which the slip rate V is stepped typically by a factor of 3 to 10. The test may yield a set of parameter values such as a, b, and d_c, but it is often the case that those determined parameters depend on V if a logarithmically wide range of V is investigated. At this point, the originally assumed constitutive law is shown to be invalid, strictly speaking, and thus need to be modified. For example, the experiments by Dieterich [1978] show that the rate-dependency $\partial f_{ss}/\partial \ln(V)$ increases as V increases, which can be explained by introduction of a cut-off time for healing [Okubo, 1989]. Such a proposal of a new constitutive law with a corresponding microphysical interpretation is a great advance in technology which enables us to implement a complex rate-dependency into earthquake sequence simulations, as well as in understanding of physics of rock friction and earthquake generation process. However, not all experimental data showing complex rate-dependency have been digested and implemented in a rate- and state-dependent framework. In this study, we propose a simple modification to the logarithmic RSF which enables implementation of rate-dependencies ($\partial f/\partial \ln(V)$ and $\partial f_{ss}/\partial \ln(V)$) that change with $\ln(V)$.

Sawai et al. [2014, AGU fall meeting] conducted a series of velocity-step tests with a core sample obtained in JFAST project at 50 MPa effective normal stress σ_e, 50 MPa pore water pressure, various temperatures T from 20 ^{o}C to 200 ^{o}C, and V from 0.3 to 100 μm/s. They found that with increasing V, the rate-dependency $\partial f_{ss}/\partial \ln(V)$ increases from negative to positive at T = 20 ^{o}C, decreases from positive to negative at T = 100 ^{o}C and 150 ^{o}C, and decreases more remarkably but stays positive in the studied range of V at T = 200 ^{o}C. In order to account for these complex rate-dependencies, we modified the logarithmic RSF to a quadratic form:

$f = f_0 + F_1 L_V + F_2 L_V{}^2 + G_1 L_W + G_2 L_W{}^2$

where $L_V = \ln(V/V_0)$ and $L_W = \ln(d_c/V_0\theta)$, f_0 is a reference friction coefficient at a reference slip rate V_0, F_1, F_2, G_1, and G_2 represent rate-dependencies which are assumed to be given by quadratic functions of ambient temperature T, and θ is the state variable representing recent slowness which evolves with a characteristic slip d_c:

$d\theta/dt = 1 ? V\theta/d_c$.

Note that at a steady-state, $L_V = L_W$ and

$f_{ss} = f_0 + (F_1+G_1)L_V + (F_2+G_2)L_V{}^2$.

This is a generalization of the aging law, the original version corresponding to $F_1 = a$, $F_2 = 0$, $G_1 = -b$, and $G_2 = 0$. We determined the rate-dependency functions by least-squares method from the experimental data by Sawai et al. [2014], and investigated the consequence by means of dynamic earthquake sequence simulations [e.g., Lapusta et al., 2003].

In preliminary simulations, we simulated earthquake sequences on a planer fault in 2-D (mode II) problems with depth-dependent T, depth-dependent σ_e, and a rotation axis to mimic intersection of the fault plane and the surface. Distributions of T and σ_e are determined to be consistent with the heat-flow measurement and modeling by Gao and Wang [2014].

Without additional complexity such as patch-like asperities and high-velocity weakening (e.g., thermal pressurization of pore fluid [Noda and Lapusta, 2013]), earthquakes are nucleated at about 30?50 km downdip from the trench where $\partial f_{ss}/\partial \ln(V)$ is negative regardless of V, and rupture only the shallowest part of the plate interface. The nucleation is preceded by slow slip in the shallower part of the plate interface where $\partial f_{ss}/\partial \ln(V)$ changes its sign with increases V and thus spontaneous acceleration to coseismic slip rate cannot occur. Effect of thermal pressurization and interaction of the system with embedded rate-weakening patches generating earthquakes shall be discussed in the presentation.

キーワード: 地震サイクル, 摩擦構成則, 数値シミュレーション, 摩擦実験
Keywords: Earthquake cycle, Friction constitutive law, Numerical simulation, Friction experiment