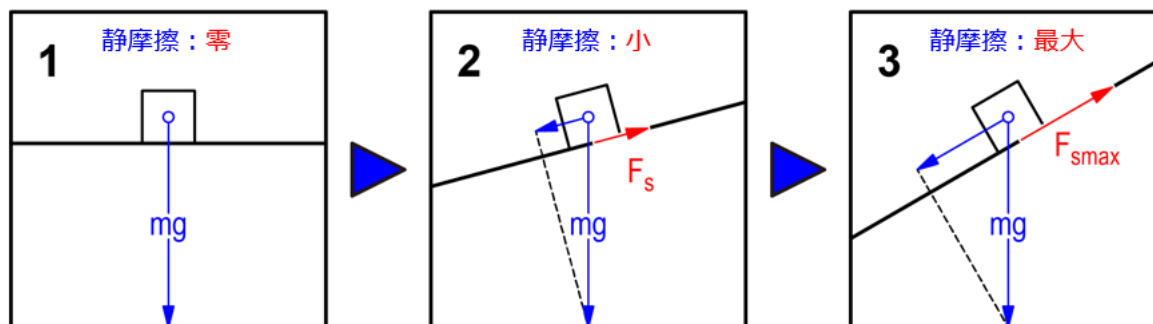


静摩擦係数と動摩擦係数の違い
は？

静摩擦係数と動摩擦係数の違いは？

Q: 静摩擦係数と動摩擦係数の違いは何ですか？

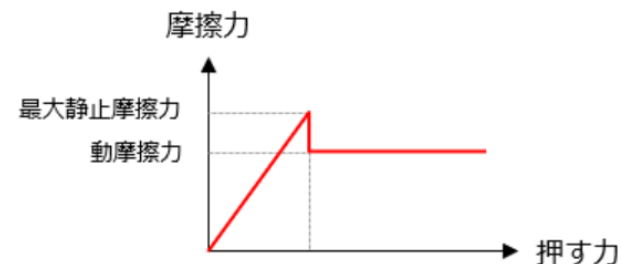
A: 静止摩擦係数と動摩擦係数の大きな違いは、物体が「動き出す瞬間（最大摩擦）」か「動いている最中（滑り中）」かという状態の違いである。例えば以下のように斜面に物を置き、滑り始める角度が大きいほど静摩擦係数が大きいとされる。



静摩擦係数と動摩擦係数を比較すると、一般的に以下のように示す。

静摩擦係数 (μ_s) > (もしくは >>) 動摩擦係数 (μ_d)

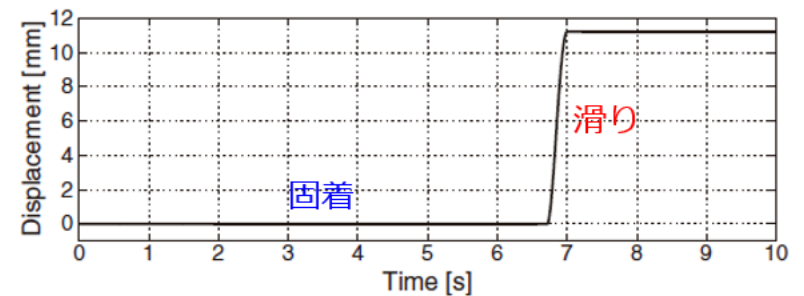
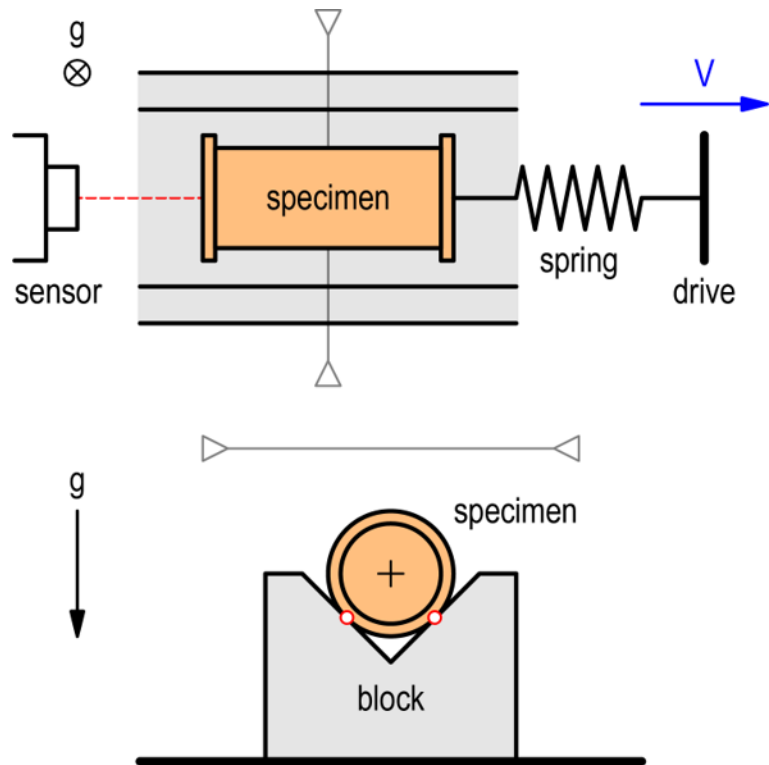
高校物理の教科書にも同様に記載されている。実生活においても、床に滑らないように立って踏ん張っているが、より強い力が働いて一旦滑り始めると止まらないで滑ってしまう。静摩擦係数が高く、ある時点で動摩擦係数急に低くなるからそうなるのかと経験する。



はたして本当にそうなのか？ 静摩擦係数と動摩擦係数は不連続なのか？
最新の研究結果を以下に紹介する。

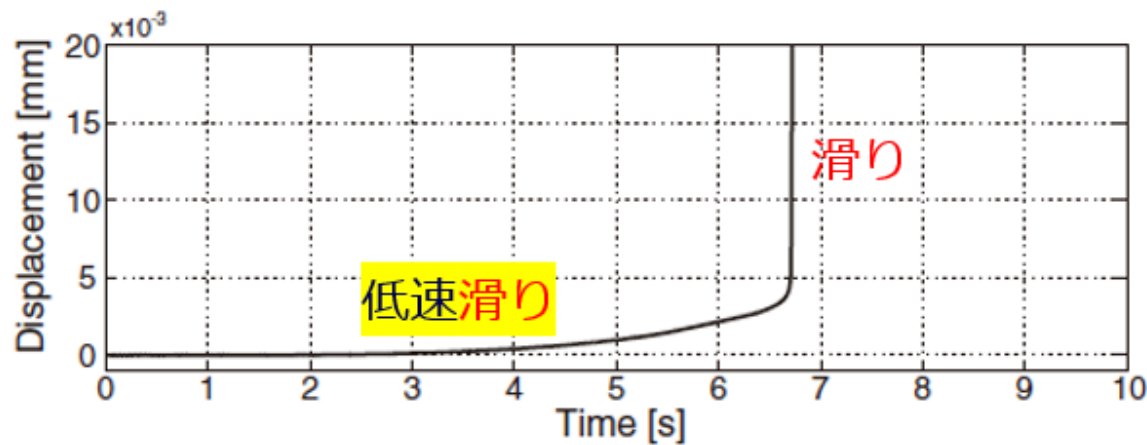
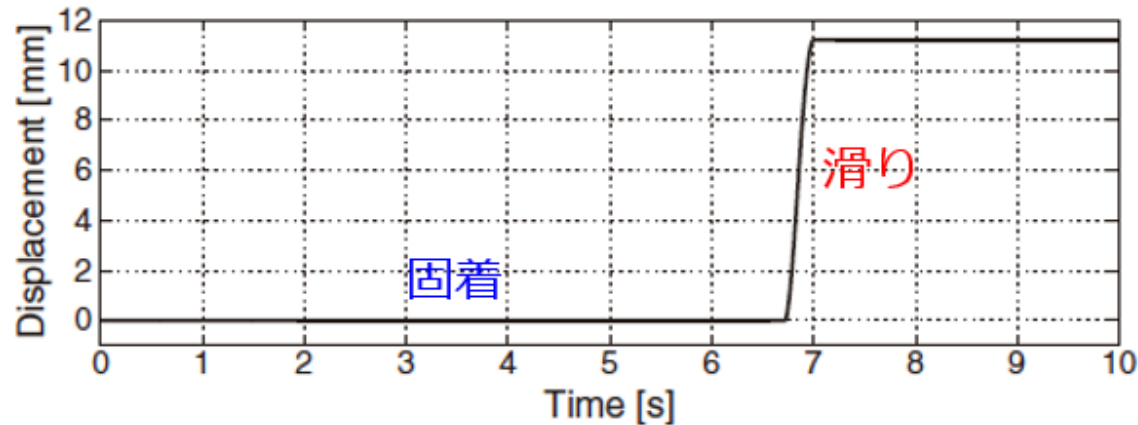
Popov et al: *Tectonophys* (2012)の実験装置を以下に示す。Vブロックの上に両端の径が大きい円柱の試験片を滑らせた（下左図）。この時の実験結果を下右図に示す。

固着した状態（静摩擦）から滑り（動摩擦）の不連続の結果となっており，従来と同じであると思われる方が大半であると推察する。



ところが縦軸を拡大すると下図のようになる（下図の縦軸は $\times 10^{-3}$ ）。静摩擦と動摩擦は不連続になっておらず、静摩擦と動摩擦の連続性が確認された。

現時点ではこの考えはまだ主流になっていないので今後の研究に期待したい。





Rate and state dependent friction laws and the prediction of earthquakes: What can we learn from laboratory models?

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ABSTRACT

Earthquakes can be considered to be a result of tribological instability in the system of faults of the Earth's crust. Similar instabilities can be reproduced and studied in detail in laboratory-scale experiments. In this work, the earthquake model under study is a tribosystem with pronounced stick-slip behavior. Measurement of the motion of the system with a resolution of 8 nm shows that slow creep is actually observed throughout the stick stage and it accelerates as the instability point is approached. This motion is regular enough to serve as a basis for the prediction of the onset of instability. It is shown that the motion of a solid, both at the stage of slow creep and at that of fast slip is well described by Dieterich's friction law, which takes the dependence of friction on sliding velocity and internal state variable into account, if we supplement it with the contribution of local contact compliance. In the immediate vicinity of the instability point, a universal behavior is observed, making highly accurate prediction of the onset of unstable slip from creep observations possible. We show that observation of the creep preceding a tribological instability makes both short term and long term predictions of the time until unstable sliding in laboratory models possible. The problems of extending this approach to real distributed systems are discussed.

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1. Introduction

The huge economic and social damages brought about by earthquakes make their prediction an important seismological problem. The Earth's crust consists of tectonic plates which move slowly relative to one another due to convection in the upper mantle (Scholz, 1998, 2002). On time scales of millions of years, these motions determine the structure of the Earth surface. On small time scales, these motions are responsible for earthquakes. Earthquake models are based on the fundamental observation that earthquakes do not arise as a result of a sudden formation and propagation of new cracks in the Earth's crust, rather they take place as a result of a sudden sliding along already existing faults. Therefore, earthquakes are more a phenomenon of frictional physics than of fracture mechanics.

Since the publication of Brace and Byerlee (1966), earthquakes were understood to be a type of stick-slip instability. A characteristic peculiarity of these processes is that fast motion accompanied by relaxation of accumulated stress begins only as the stress reaches a certain critical level. Before this level is reached, the system is in equilibrium showing no evidence of its proximity to the critical state. An extension of this to continua does not fundamentally change anything regardless of how complicated the system becomes. A distributed system exhibits complicated behavior, which is mirrored by the known statistical properties of

earthquakes (Carlson and Langer, 1989; Gutenberg and Richter, 1954; Omori, 1984; Popov, 2010; Filippov and Popov, 2010). These properties, however, have a purely statistical character. Therefore, they are useful for a *a posteriori* analysis, but not for prediction at a given place and time. The threshold response of a system is a primary physical cause for the challenge of earthquake prediction. In view of the above peculiarity, some authors think that earthquakes are impossible to predict at all (Geller, 1997; Geller et al., 1997).

This conclusion, however, is based on a concept that is not completely correct. Both the theory of friction and the theory of plastic deformation state that before the macroscopic stability limit is reached, creep is always observed due to microstructural stress concentrators and thermally activated deformation. From theoretical considerations it is apparent that creep rapidly speeds up in close proximity to the threshold.

On this basis many noted scientists involved with mechanisms and dynamics of earthquakes consider earthquake prediction possible (Dieterich, 1992; Dieterich and Kilgore, 1996; McGuire et al., 2005; Mjachkin et al., 1975; Scholz, 2002; Thurber and Sessions, 1998). The question is only whether the processes of slow creep are well measurable and are universal enough to provide the basis for reliable prediction of the onset of instability.

For this question to be given an experimental answer, we studied a simple tribological model with pronounced stick-slip behavior (this model was described and studied earlier for the possibility of influencing the statistics of earthquakes (Popov and Starcevic, 2006)). Leaving aside the possibility of extending the research results to real earthquakes occurring in much more complex systems, we

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