Effect of humidity on the frictional properties of synthetic quartz gouge at intermediate- to high-velocity slip

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It has been clarified that various types of rocks and fault gouges cause weakening of frictional strength in the high slip velocity range. It is known to be caused by decomposition. On the other hand, in the experiment using quartz rocks, the friction strength began to weaken in the low velocity range near 1 mm / s, where there is almost no frictional heat (Di Toro et al., 2004). As a cause of weakening of frictional strength of this quartz rocks, Gel lubrication model in Goldsby and Tullis [2002] states that a gouge of hydrated amorphous silica is formed on the friction surface, and frictional weakening is caused by its lubrication effect. However, the relationship between the weakening of friction strength and the hydration and amorphization of gouge on the fault surface is not yet clear.
The purpose of this study is to elucidate the mechanism of frictional strength weakening in quartz rocks. We conducted two types of experiments -frictional slip experiment and Slide-Hold-Slide experiment. In these experiments, we observed the time-depended difference in friction behavior under different humidity conditions.
All experiments were performed using a rotating medium-high velocity friction tester from Kyoto University. In order to observe the friction behavior of pure quartz, an synthetic quartz rock was used as an experimental sample. Friction experiments were performed at 5 MPa, 10 μm/s, 105 μm/s, 1 mm/s, 10 mm/s and 105 mm/s under constant normal stress conditions of 1.5 MPa. In this study, we focus on the supply of water molecules by humidity, so we set humidity 0 %, 5 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 % and 80 %. For each humidity condition, the flow rate of the dry air and humidified air fed into the sample chamber was adjusted by controlling the hygrometer output near the sample as a feedback signal.
As a result of the frictional slip experiment, friction weakening behavior (negative velocity dependence) was observed under all humidity conditions, but the friction behavior was different depending on the humidity conditions. If the slip velocity exceeds 10 μm/s, the friction strength decreases as the humidity decreases. In the range of 0 to 20% humidity, the humidity and the coefficient of friction were almost positively correlated. At a humidity of 20% or more, the steady value of the friction coefficient was almost constant, and the value had a negative dependence on the velocity.
And more, as a result of the Slide-Hold-Slide experiment, we observed time-depended frictional healing. Under the dry condition (0 % humidity), healing did not occur in range of 0- 100000 seconds, but under high humidity, frictional healing occurred with shorter holding time.
From the experimental results, it is clear that the humidity (the presence of water molecules) affects the frictional strength in the speed range from 10 um/s to 105 mm/s. In this study, we proposed a dynamic model to show the effect of "water" on gouge friction weakening / strengthening. The presence of water molecures causes a chemical reaction, causing a change in frictional strength.

Keywords: friction slip, frictional weakening, gouge

