

Broadband excitation of acoustic emission in granular stick-slip : experiments and spectral analyses

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Slow slip and tremor are observed to occur simultaneously (e.g., Rogers and Dragert, Science, 2003). Such observation can be modelled using granular stick-slip experiments which show that the timing of the slips and acoustic emission (AE) are well correlated (e.g., Johnson et al., GRL, 2013, Jiang et al. GRL, 2017). AE waveforms are complex (e.g., Michlmayr & Or, Gran. Matt., 2014), and we do not fully understand the details of the temporal change of AE during the slip. Here we report the results of granular stick-slip experiments which focus on how their spectra depend on the shear rate, particle size and container size.

We shear glass beads contained in a stainless steel beaker using a rotating viscometer to which a vane spindle is attached (Higashi and Sumita, JGR, 2009), and measure the shear stress and AE at 200kHz. We use broadband accelerometers and microphones to measure AE. Four accelerometers are attached at the outer rim of the beaker, and each are separated by an angle of 90 degrees.

We integrate the acceleration to obtain AE velocity –time series data and analyze their characteristics in broad band. We find that although AE has a broad spectrum, the spectra show that there are two characteristic frequency (f) components ; a high-f (of the order of 100 Hz) and a low-f (of the order of 10Hz) components. The velocity waveforms recorded at antipodal positions, show that the high-f components are in phase, whereas the low-f components are of the opposite phase. This indicates that the mechanism which excite these components differ : the high-f component may correspond to AE excited by particle rearrangement, whereas the low-f component may correspond to the translational motion of the container. Indeed we find that the frequency of the low-f component depends on the container size.

We also conducted experiments using a rheometer in a parallel-plate setup and confirmed that these two different components exist. When the particle size becomes larger, the amplitude of the shear stress and the AE velocity increases. Furthermore we find that the mean frequency of the normalized power spectra rose to a higher frequency, thus correlating with the stress increase.

Our experiments indicate that AE is excited in broadband, and that their frequency components can be used to infer the interparticle stress. Such excitation appear to be analogous to tremors and very low frequency earthquakes that are also excited simultaneously.

Keywords: granular matter, stick-slip, acoustic emission, earthquake, tremor