Electrical Anomalies Observed During Frictional Stick-Slip in Granular Materials

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Introduction

We present data from double direct shear experiments on granular synthetic fault gouge in which the electrical potential difference between the gouge layers and system ground was monitored with a non-contact electrostatic voltmeter. Data were obtained for different humidity conditions, loading velocities, and particle size distributions. We find that electrical potential varies systematically during repetitive stick-slip frictional sliding. Careful measurement shows that observed electrical signals are not inﬂuenced by other external factors (i.e., apparatus and environment).

Potential Causes of Electrical Charge

Piezoelectricity - Charges resulting from strain of certain materials
Triboelectricity/Contact electrification - Potentials resulting from contact of different materials or charges generated during frictional rubbing and contact separations
Potential Effects of Electrical Charge

- Ceramic Shocks and Earthquake Lights
- Magnetic and Radio Perturbations
- Anomalous Biological Effects/Behavior
- High Remnant Magnetization in Pseudotachylite Veins
- Magnetic and Radio Perturbations

Materials and Methods

We shear soda-lime glass beads in a double direct shear conﬁguration exposed to room humidity. 100% humidity, and submerged in de-ionized water. Plexiglass forcing blocks were used to electrically insulate the granular material from the loading frame. The surface of the blocks is roughened to reduce edge effects. Two grain size distributions 100-150µm (pictured) and 420-500µm were tested at room humidity conditions. All experiments were conducted with 5mm thick layers at 4MPa normal stress. Load point velocity was varied from 0.4 to 1.6 mm/s.

Electrical Mechnanism

Hypothesis of Electrical Mechanism
1) An shear load is applied, then shears chain to support the load. This is a ‘fragile system’ conﬁguration.
2) Small piezoelectric charges result from grain rearranging.
3) Deformation of contact junctions within force chains streams electron contacters, making highly stressed regions negatively charged.
4) Force chains fail and stress drop occurs. Return currents neutralize contact junctions.
5) Acoustic wave passage adds migration of positively charged holes.

Mechanical and Material Parameters

- Monitor surface potential of beads with respect to system ground
- Measurement accomplished by measuring AC signal resulting from electrophysical oscillation of a capacitive probe. When probe voltage matches the surface voltage the AC component is extinguished.
- Capacitive 1-30V to 20VAC measurement
- All data recorded at 24-bit resolution
- Several positions analyzed with similar results.