Abstract

The microstructure of ductile shear zones differs from that of surrounding wallrocks. In particular, compositional layering is a hallmark of shear zones. As layered rocks are weaker than their isotropic protolith when loaded in simple shear, layering may hold the key to explain localization of ductile deformation onto ductile shear zones. I propose here a constitutive model for layer development. A two-level mixing theory allows the strength of the aggregate to be estimated at intermediate degrees of layering. A probabilistic failure model is introduced to control how layers develop in a deforming aggregate. This model captures one of the initial mechanism of phase interconnection identified experimentally by Holyoke and Tullis (2006a, b), fracturing of load bearing grains. This model reproduces the strength evolution of an aggregate to be estimated at intermediate degrees of layering. A two-level mixing theory allows the strength of the shear zones. I propose here a constitutive model for layer development and resultant strength decrease is compared with the laboratory experiments of Holyoke and Tullis' (2006). Where KH represents the elasticity of the machine and \( \varepsilon \) is the externally imposed strain rate, constant in time. The system of ODE is integrated forward in time with initial conditions \( \varepsilon = 0 \) and \( \sigma = 0 \). The stiffness \( KH \) is determined from the initial linear portion of the stress/strain curves.

Comparison with experiments

The proposed model of fabric development and resultant strength decrease is compared with the laboratory experiments of Holyoke and Tullis’ (2006). The evolution equation and rheological formulation are coupled with an elastic loading equation that describe the experimental apparatus.

\[
\frac{d\sigma}{dt} = KH\varepsilon - \sigma
\]

where \( KH \) is the stress rate and \( \varepsilon \) is the externally imposed strain rate. The stiffness \( KH \) is determined from the initial linear portion of the stress/strain curves.

Aggregation description

The aggregate is formed of several minerals with abundance \( \phi_i \) each obeying a power law relation between strain and stress.

\[
\begin{align*}
\varepsilon &= A_i \sigma^n \\
\sigma &= \sum_i \phi_i A_i \sigma^n \\
\varepsilon &= \sum_i \phi_i A_i \sigma^n
\end{align*}
\]

Initial State: Isotropic

In the protolith, the stronger minerals form a load-bearing structure, the other with layered structure. Their rheology is given by the constant strain rate and constant stress approximation. As the pseudophases are randomly distributed, I assume that the strain rate is the same between each pseudophase. The aggregate behavior is then given by:

\[
\begin{align*}
\varepsilon &= \sum_i \phi_i A_i \sigma^n \\
\sigma &= \sum_i \phi_i A_i \sigma^n \\
\varepsilon &= \sum_i \phi_i A_i \sigma^n
\end{align*}
\]

Intermediate state

If a fraction \( f \) of the aggregate is layered, I consider that two pseudophases are present in the aggregate, one with isotropic structure, the other with layered structure. Their rheology is given by the constant strain rate and constant stress approximation, respectively. As the pseudophases are randomly distributed, I assume that the strain rate is the same between each pseudophase. The aggregate behavior is then given by:

\[
\begin{align*}
\varepsilon &= \sum_i \phi_i A_i \sigma^n \\
\sigma &= \sum_i \phi_i A_i \sigma^n \\
\varepsilon &= \sum_i \phi_i A_i \sigma^n
\end{align*}
\]

Final state: Layered

In the shear zone, each phase forms an interconnected layer so that the response to layer-parallel shear is given by the constant stress approximation.

\[
\begin{align*}
\varepsilon &= (1-f) A_i \sigma_i^n + f A_i \sigma_i^n \\
\sigma &= (1-f) A_i \sigma_i^n + f A_i \sigma_i^n \\
\varepsilon &= (1-f) A_i \sigma_i^n + f A_i \sigma_i^n
\end{align*}
\]