Structural Styles of Fracture-Vein Interaction: Insight into the Crack-Seal Process from 3D-DEM Modelling.

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Observations from crack-seal vein systems suggest that preexisting veins can strongly influence fracture localization and propagation in a rock even in cases where the orientation of the stress field is incompatible with the orientation of the new fracture. We investigate how existing veins interact with extension fractures in rocks using 3D Discrete Element Method models with a geometry inspired by tension tests with notched samples.

The model consists of a plate shaped dense packing of ~ 250.000 particles connected via brittle-elastic bonds. The failure criterion of the brittle bonds takes normal, tangential, bending and torsional components of the deformation into account. A Vein is introduced into the material by changing the parameters of the brittle bonds within a tabular volume extending through the model. A quasistatic uniaxial tension is applied to the models via servo-controlled walls. An unbonded notch at the center of the lower edge initiates fracturing.

In a sensitivity study we varied the misorientation angle between the vein and the bulk extension direction, and the strength ratio between host rock and vein material.

Results show range of vein-fracture interactions, which fall in different, robust, "structural styles". Veins, which are weaker than the host rock, tend to localize fracturing into the vein, even at high misorientation angles. Veins, which are stronger than the host rock cause deflection of the fracture tip along the vein-host rock interface. Fractures are arrested at the interface from weak to stronger material. When propagating from a stronger to a weaker material, macroscopic bifurcation of the fracture is common. Complex interactions are favored by low angle between the vein and the fracture, and by high strength contrast. The structural styles in the models show good agreement with micro- and meso- structures of crack-seal veins found in natural systems.

We propose that these structural styles form the basis for criteria to recognize strength contrasts and stress of crack seal systems in nature.

References

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