NUMERICAL INVESTIGATION OF IN-SITU STRESS PERTURBATION NEAR A WEAK FAULT BY 3D DISPLACEMENT DISCONTINUITY METHOD

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Abstract

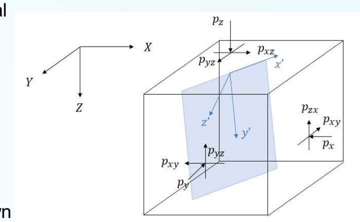
In this paper, a numerical investigation utilizing the 3D displacement discontinuity method is performed to examine the stress perturbations and induced displacements near a weak fault. The modelling is constructed based on indirect boundary integral equations. In this work, the fault plane is first modelled as a rectangular plane which is then divided into numerous rectangular boundary elements with imposed shear singularities on the surface which is normal to the fault plane to simulate a traction-free scenario. The numerical results of the total induced stresses and displacements are then compared to existing solutions of a penny-shaped crack for validation purposes. With verified results, the paper discusses various factors that have impacts on the induced stress and displacements: aspect ratio, strike direction, and dip angle.

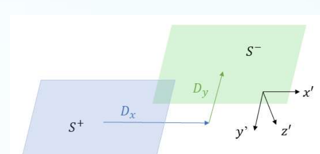
Introduction

At regions where a fault zone is in vicinity, the alteration of direction and magnitude of the principal stresses as well as induced displacements should be expected. In this research, we focus on investigating the impacts of various parameters influencing the stress perturbation near a weak fault with too low of the shear strength to restrict the reorientation of the induced principal stresses. 3D displacement discontinuity method (DDM) as a modification of the boundary element method, is used to carry out numerical experiments on different scenarios of investigations, including impacts of aspect ratio, dip angle, strike direction, and rectangular/elliptical shaped fault plane configuration.

Methodology

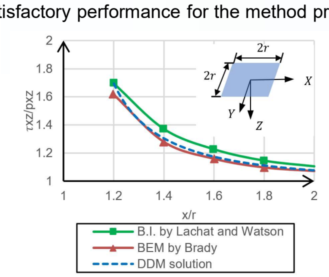
The elastic law is fundamental for the numerical computations of DDM. Consider a fault plane with negligible thickness and arbitrary dip and strike direction, as shown in the top figure. The 3D boundary is discretized into finite pairs of planar DD elements, as shown in the bottom figure. Various distributions of fictitious shear singularities on each DD element are used to replicate the scenario of a weak fault with zero normal displacements. Series of equations are derived to express induced stresses and displacements with respect to the shear singularities, which can be determined with prescribed far field stresses.





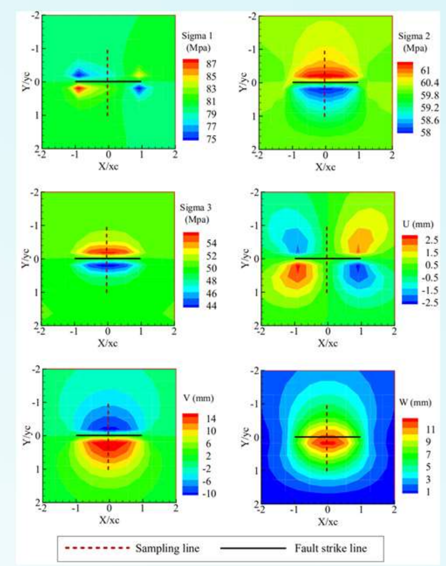
Validation

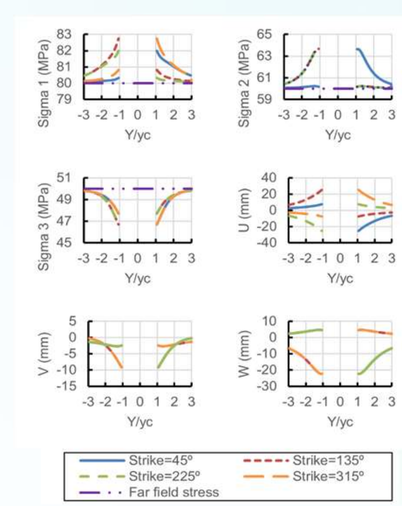
The results of the model discussed are compared to two existing sets of numerical simulations for stress distributions evaluated for a mining excavation around openings in a tabular orebody. Similarities of both trend and magnitude for the DDM solution observed from the figure below indicate a satisfactory performance for the method proposed.



Numerical Experiments

With validated DDM solution, numerical experiments are performed on an arbitrary fault plane. The prescribed principal stresses correspond to a thrust faulting stress regime of the far field. Six contour plots are generated for a reference case with a dip of 60° and strike parallel to the X-axis, as shown in the figure. The induced principal stress sigma 1 and displacement U both show a point-reflection nature about the midpoint of the fault strike line; rough symmetry can be observed for the remaining induced stresses and displacements about the strike line.





Series of 1D plots consisting of the three induced stress components and three displacement components are generated to visualize the differences between various scenarios by changing the aspect ratio, dip, strike direction, as well as the geometrical configuration of the modeled plane. Figure to the left as an example is the comparison made to simulate increasing strike direction with respect to the global X-axis.

Conclusion

The numerical experiments performed led to the following conclusions, each corresponds to one factor examined influencing the induced stress and displacement near a weak fault:

- **Aspect ratio:** The Deeper a fault penetrates, the larger the in-situ stress perturbation;
- **Dip angle:** Dip angle influences stress states and deformations ununiformly;
- **Strike direction**: Fault planes that share the same strike line and opposite dipping directions have same degree of perturbations on the opposite side of the fault. Fault pairs with strike directions that are symmetrical by the local *X*-axis bare identical degree of perturbations for its in-situ stress state that has symmetrical spatial distribution.
- **Fault plane geometry**: The elliptically modeled fault plane will have smaller induced displacements than the rectangular fault plane. The selection of model can be made based on the characterization of the discontinuity geometry.

These findings provide useful references for local in-situ stress perturbation characterization and faulting monitoring in mining, petroleum, and civil engineering as well as in earth science, where results can vary when impacts of aspect ratio, dip, and strike angle are not well considered.

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Acknowledgement

Support of the Natural Sciences and Engineering Research Council of Canada (NSERC) is greatly acknowledged.