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Unconventional Reservoir Geomechanics
Spring 2019

Homework 4: Stress on Faults

Due May 20, 2019 at 08:00 UTC
Please direct any questions to the Piazza Discussion Forum on the course page

Background

This assignment focuses on using Coulomb faulting theory to determine how faults are activated during shear stimulation. You will use Mohr circles to identify active faults under different stress states. The fault data used in this assignment in given in file HW4_Fracture Data.txt. A MATLAB script entitled "stress_on_faults.m" is included on the course page to demonstrate how shear and normal stress on faults is calculated, but it is not required for the homework assignment.

Utilize a scientific computing and/or plotting program such as MATLAB, Python or Excel to follow the steps below. Then, answer the questions on the page below.

Part 1

(a) *Construct a Mohr circle diagram*. Consider a normal faulting stress state with vertical stress S_v = 42.55 MPa and hydrostatic pore pressure P_p = 18.96 MPa. Chose an intermediate stress such that φ = 0.5. Recall that φ quantifies the relative differences between the three principal stresses.

$$\varphi = \frac{S_2 - S_3}{S_1 - S_2}$$

On a Mohr diagram (*e.g.*, Figure 1), plot effective stresses, $\sigma_i = S_i - P_p$, where i = 1,2,3 corresponds to the principal stresses. Plot the frictional failure line given by $\tau = \mu\sigma_n$, where τ is the shear stress, σ_n is the normal stress and μ is the coefficient of sliding friction. Use μ=0.6, which corresponds to an intermediate value of clay + TOC of 25 wt%.

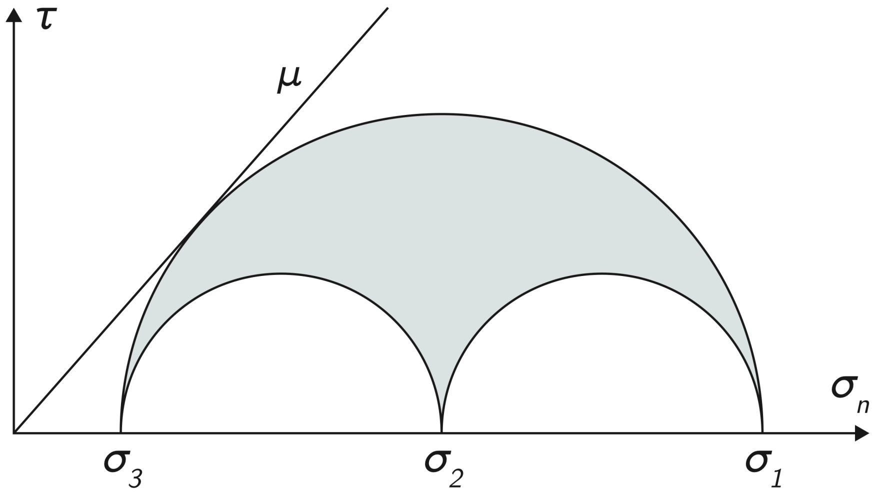

Figure 1. Representation of a 3D effective stress state in a Mohr circle diagram. The area bounded by the three half circles indicates the range of possible values for shear and normal stress on fault planes. Each location in the bounded area corresponds to a fault plane of a particular orientation relative to the principal stresses. To avoid distortion of the half circles, the horizontal axis and the vertical axis should be the same scale (no horizontal or vertical exaggeration).

(b) *Plot the stress on fault planes*. Assume S_{Hmax} is orientated E-W (Strike = 90°). Consider the fault plane orientations in the table below.

Fault	Strike - azimuth w.r.t North (°)	Dip (°)	Shear stress (MPa)	Normal stress (MPa)
1	90	60	7.16	11.19
2	60	90	3.57	9.13
3	45	45	6.85	17.4
4	30	0	0	23.59
5	90	30	7.16	19.46

Table 1

The shear and normal stress on each fault plane is called by first rotating the principal stresses into geographic coordinates and then to the fault coordinate system. The details of this method are provided in the reference below.

Angelier, J. (1979). Determination of the mean principal directions of stresses for a given fault population. Tectonophysics, 56(3-4), T17-T26.

A MATLAB script entitled "stress_on_faults.m" is included on the course page to show how this method is implemented, but it is not required for the homework assignment. Plot the shear and normal stresses for each fault plane on the Mohr diagram from (a). *Hint: Points corresponding to the fault planes should plot within the bounded area.*

(c) *Calculate the Coulomb Failure Function*. The Coulomb Failure Function (*CFF*) is a measure of how close faults are to failure $CFF = \tau - \mu\sigma_n$. Compute the *CFF* for each of the fault planes. Which of the fault planes is critically-stressed (most likely to be activated during stimulation)?

(d) *Shear stimulation of faults*. Consider the effects of increasing pore pressure during hydraulic stimulation in terms of an actual fracture dataset. Refer to the file "HW4_Fracture Data.txt", which contains a data similar to Table 1. The first two columns are the strike and dip of fracture planes. The next two columns are the shear and normal stresses acting on these fractures under hydrostatic pore pressure conditions (P_p = 18.96 MPa). The two last columns are the shear and normal stresses acting on these faults after increasing the pore pressure by 3 MPa.

Perform the same Mohr circle analysis and compute the CFF for each fracture. Now consider an increase in pore pressure of 3 MPa and repeat the analysis. How many fractures are likely to activated as a result of hydraulic stimulation?

Part 2

Use the plots and calculations from Part 1 to answer the questions on the page below. The answers and solutions will be posted after the due date. Numerical entry types responses have only a limited range of accepted values and are graded electronically, so follow the directions closely and adhere the to the given values of constants to prevent misgrading of your submissions.