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Comprehensive Atlas of Stress Trajectory Patterns and Stress Magnitudes around Cylindrical Holes in Rock Bodies for Geoscientific and Geotechnical Applications

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Abstract - This study presents a comprehensive atlas comprising maps and graphs which quantify the wide range of possible stress states around cylindrical cavities when subjected to the full range of far-field stress conditions and internal net-pressures. A greater understanding of the principal stress trajectories and related stress magnitudes around stressed cylindrical holes in rock formations significantly aids the design of safer and more stable wellbores, advances our capacities in hydraulic fracturing, and provides additional insights into the nature and stability of volcanic dikes, salt domes, and caverns used for hydrocarbon and other fluid storage. The algorithms used in our study systematically non-dimensionalize the analytical Kirsch equations using two critical parameters to scale the variable boundary conditions: (1) the Bi-axial Stress Scalar, χ, describes the far-field stresses at all depths and for each of the formations penetrated by a cylindrical borehole or natural liquid-filled pipe by describing the anisotropy of the two far-field principal stresses, and (2) the Frac Number, F, specifies the net pressure on the cylindrical hole as it relates to the natural background stress in the host rock and the pressure in the penetrated formation at each depth. Manipulation of these two governing parameters (χ, F) enables us to view and monitor the stress trajectories in the host rock around a cylindrical hole at any given depth. Additionally, the neutral point locations and their effects on the principal stress orientations near the cylindrical hole have been more thoroughly investigated than in earlier studies. The neutral points form the boundaries for the "stress cage" in overbalanced cylindrical cavities and for the complimentary "fracture cage" in underbalanced cavities. The understanding of stresses induced around cylindrical holes in a rock formation is paramount in geotechnical analyses and stability appraisals of manmade cylindrical holes as well as for the geoscientific interpretation of piercing by cylindrical, fluid-filled pipes. Our stress atlas aims to provide fundamental insight and practical support for such analyses.

Keywords: Wellbore stress; Stress trajectories; Wellbore stability; Geomechanics