Numerical and Laboratory Analyses on the Role of Borehole Size on Failure Mechanisms in Thick-Walled Cylinder Tests

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Abstract

Understanding the factors effecting wellbore stability is crucial for safe and cost effective drilling and completion operations. Thick-wall cylinder (TWC) laboratory tests have been widely used to calibrate wellbore stability models. Although the TWC test is meant to simulate the wellbore geometry. The influence of the finite specimen wall thickness makes the results difficult to upscale. To account for these problems, elastoplastic models should be calibrated to laboratory tests using the MCC material model. These calibrated models were then combined with finite element analysis to investigate failure mechanisms. Three mechanisms have been postulated: Runaway Instability (RAI), when the strains at the borehole grow uncontrollably; Negative Rate of Work (NRW) of plastic strains which is interpreted to cause borehole spalling; and Considered instability, a catastrophic failure which occurs when global equilibrium conditions cannot be maintained. To investigate the effect of wall thickness and rock properties on TWC failure mechanisms, a suite of core samples was tested using both multistage triaxial and TWC tests. The Modified Cam-Clay model was calibrated to test results for the multistage triaxial and TWC tests for the three rock types (incipiently cemented Miocene Sandstone, Bentheimer Sandstone, and Austin Chalk). The MCC calibration parameters are stress dependent, meaning the parameters change depending on the experiment run. A more complicated double yield surface was also required in order to describe the most ductile rock type. A dependence of TWC test results on wall thickness was observed. The ultimate strength at which the TWC collapses increases with increasing wall thickness. Failure mechanisms

around the borehole were investigated using high resolution micro CT scanning. The three different failure mechanisms (spalling, borehole closing, and catastrophic) were all observed. The MCC model was used to further investigate stresses and deformation present inside the TWC specimen. Near wellbore failure is caused by an extensional deformation gradient that has an approximately constant magnitude for each rock type regardless of the TWC wall thickness. The near wellbore extension region extends away from the wellbore center to 140%-170% of the wellbore radius. Catastrophic failure is observed for TWC tests with wall thickness smaller than this dimension. For test performed on samples with thicker walls, borehole spalling occurs. The runaway instability was not observed due to the brittle nature of all the sediments tests, more ductile material will be used in future work.

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