



Design and Application of a High-performance True Triaxial Stress Cell



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Abstract

Conventional triaxial tests are for axisymmetric stress condition, which is not necessarily correct for deep rock layers. Thus, orthotropic stress conditions and pore pressure are better simulated by new generation of high-performance True Triaxial Stress Cell (TTSC). New TTSC in Curtin university allows stresses up to 70 MPa on a 50×50×50mm cube of the rock sample. Additionally, pore pressure can be up to 20 MPa and temperature up to 70°C. Six sets of LVDT strain gauges and 24 acoustic transducers can monitor all deformations and crack events during fracturing of a sample. Through a hole in the center of the rock, a fluid can be injected to simulate hydraulic fracturing, or investigate fault reactivation during fluid injection. All of events are monitored in real-time manner using ultrasonic seismic transducers around the sample. Further details of this equipment are explained in this paper.

Keywords: True Triaxial Stress Cells; Triaxial tests; Geomechanics

Introduction

In rock mechanics, estimation of the strength and deformations under various stress states are essential. Conventional triaxial tests are for cylindrical samples whereas a rock sample is subjected to circumferential confining pressure ($\sigma_2 = \sigma_3$) under an axial stress (σ_1). This case is only valid for seismically normal stress condition [1]. However, there is often orthogonal stress condition ($\sigma_1 \neq \sigma_2 \neq \sigma_3$) in deep rock layers, which affects the drilling stability, seal integrity in petroleum engineering [2]. This condition can be due to anisotropy of rock properties, faulting systems and various tectonic conditions. Accordingly, cubic rock samples are tested in True Tri-axial Stress Cells (TTSC). These facilities replicate the real stress environment in ground to develop the knowledge of rock mechanics effectively [3-5].

Background

Researchers at Curtin University developed the first cell of this kind in Australia in 2010 to investigate various geomechanical models including hydraulic fracturing, sand production etc. [6]. It was to accommodate the samples up to 300mm dimensions like the one developed by Haimson et al. [7]. It could provide lateral and vertical stresses without surrounding pore pressures. Accommodation of small samples requires spacers to transfer the loads over samples in various sizes. Deformations in each direction can be recorded by Linear variable differential transducers (LVDT) attached to each loading ram. Syringe or Hydraulic pumps with

pressure capacity up to 103.5MPa can be used to exert stresses over surfaces. For hydraulic fracturing, fluid injection can be either in constant flow rate with a maximum capacity of 650 cc/hr or constant pressures or any other loading patterns introduced to syringe pumps. Deflections of rams also can be up to 20mm, which is quite enough for most cases. The main capability of this facility is acoustic emission and acquisition system. This feature enables users to monitor acoustic events due to any fracture move. Sixteen sensors in real time are responsible to capture the signals from all directions to map crack propagation due to stress anisotropy.

New TTSC Facility

With support of National Geosequestration Laboratory (NGL), new equipment was developed by Curtin University in 2016. It was to deliver innovative solutions into carbon storages projects in Australia. This cell is for 50mm cube samples with capacity of providing pore pressure around or into samples via hot fluid or gas as shown in Figure 1. The design and fabrication of 50mm cell has been inspired basically by 30cm standard TTSC built in 2010 and the one developed in Petrobras Research and Development Center [8]. The main difference of this new cell with the previous ones in its internal design and functionality mainly about sealing systems that are closely based on similar small cell in Brazil. This new cell of 50mm cell has injection or pore pressure systems adjustable according to high temperature, corrosion resistance requirements

as well as delicate acoustic system. This cell is easier to assemble with reduced number of components specifically for load system. This in turn clearly lowers the associated maintenances, which are a challenge in its maintenance. The seals are mostly compressional

with broad area for crushing of Viton or Polyurethane sleeve plus O-rings as double barrier any likely leakage. Steel grade was 4140 because of its higher strength and availability of 70cm steel blocks in Perth for machining purposes.

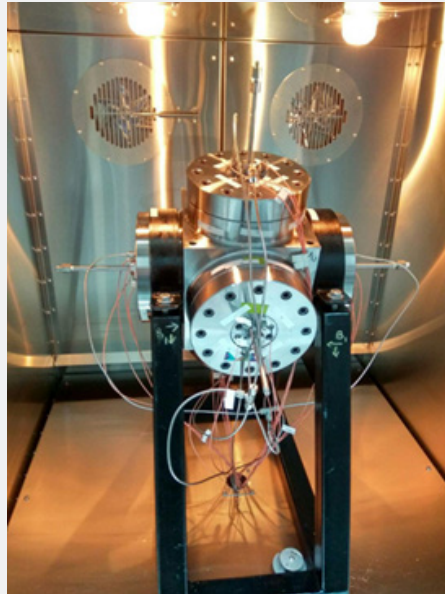


Figure 1: General configuration of new 50mm TTSC.

Ultrasonic System

This TTSC primarily is built for laboratory-based CO₂ injection studies. Previous cell in 2010 included ultrasonic transducers on all six sides of rock specimen, whereas transducers being pressed by springs within recessed indentations anticipated on loading faces [9]. New 50mm TTSC have 4 transducers per face, amounting to a total of 24 transducers each being sampled at every 0.1 μ sec [10,11]. All transducers will have the ability to record data in listen mode continuously recorded into a standard memory using software based on Labview. Once an event is observed (a peak in amplitude), the signal timing is adjustable to 200 μ sec before the event and 300 μ sec after the event. A knowledge of the velocity field of the block is obtained by pulsing all transducers once with all other transducers recording, to provide a calibration database of the velocity field of the block. Using this database, a 3D location and display of each event's origin is computed as conventionally processed in acoustic emission processing [12,13].

Conclusion

The new 50mm TTSC system provides unique opportunities to expand the knowledge of advanced tests in Geomechanics by allowing real time monitoring of cracks in rock specimens.

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Conflict of Interest

The authors certify that they have NO affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

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