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Energy Procedia 88 (2016) 544 – 551

Energy Procedia

CUE2015-Applied Energy Symposium and Summit 2015: Low carbon cities and urban energy systems

Deformation mechanics and acoustic propagation in reservoir rock under brine and oil saturation: An experimental study

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Abstract

Deep saline aquifers and depleted oil fields have been identified as two main potential geological sinks for CO_2 sequestration due to their preferable geological conditions. However, correct understanding of their in-situ chemico-mechanical properties (prior to CO_2 injection) is necessary to evaluate their safe and long-term CO_2 storage potential. This study therefore investigated the effect of brine and oil saturations on the mechanical and acoustic properties of reservoir rock by performing a series of strength tests using acoustic emission technology. According to the test results, the mechanical responses of reservoir rocks vary with the saturation condition, and the existence of brine and oil in water-saturated reservoir rocks causes their mechanical properties to be noticeably enhanced.

Peer-review under responsibility of the organizing committee of CUE 2015

Keywords: Compressive strength; CO_2 sequestration; deep saline aquifers; oil fields

1. Introduction

Full understanding of the mechanical behaviour of reservoir rock under various saturation conditions is required in many civil, mining and petroleum engineering applications, including waste disposal, tunnelling, oil recovery, and CO_2 sequestration. CO_2 geo- sequestration in depleted oil reservoirs and deep saline aquifers offers one of the most promising solutions to the continuously increasing anthropogenic

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Peer-review under responsibility of the organizing committee of CUE 2015
doi:10.1016/j.egypro.2016.06.076

CO_2 emissions into the atmosphere. Table 1 shows the worldwide capacity of potential CO_2 storage reservoirs [1].

Nomenclature

EOR	enhanced oil recovery
AE	acoustic emission
GtC	billion metric tons of carbon equivalent

Although geological sequestration is a technologically feasible and verifiable option to mitigate anthropogenic CO_2 emissions [1], dumping vast quantities of CO_2 into deep geological reservoirs may have harmful effects on their hydro-mechanical properties, and the possibility of CO_2 leakage into surrounding fresh water aquifers raises questions regarding long-term integrity of the process. To correctly identify such risks, it is necessary to have a precise understanding on the in-situ chemico-physical properties that may significantly differ from those of normal water- saturated rocks due to the presence of brine and oil. This study was carried out to identify such effects by conducting a series of compressive strength tests using acoustic emission (AE) technology, in which the fracturing processes of oil-and brine-saturated reservoir rocks were characterised. It is believed that the findings will be highly useful in understanding the effect of wetting by oil/brine on reservoir rock fracturability during EOR and sequestration processes.

Table 1. The worldwide capacity of potential CO_2 storage reservoirs [1]

Sequestration option	Worldwide capacity
Deep saline aquifers	100s-1000s GtC
Depleted oil and gas reservoirs	100s GtC
Un-mineable coal seams	10s-100s GtC

2. Sample preparation

The sandstone blocks were collected from the Sydney basin in New South Wales, Australia and belong to the Triassic geological age. The mineralogical structure of this sandstone is 80% quartz, 10% calcite, 5% kaolinite, 2% anatase, 1% siderite, 1% mica, and 1% amphibole, and the main cementing phases are quartz, calcite, and kaolinite. Homogeneous sandstone blocks were first carefully selected and then cored to the required size to produce samples 38mm in diameter and 76mm high, maintaining the required ASTM standard (2:1 height-to-diameter ratio) [2]. Both ends of the specimens were then ground. The prepared samples were first oven-dried at 30^0C for 48h (a temperature of 30^0C was selected to avoid micro-structural damage). Ten sets of three samples were then kept in distilled water, brine (15% NaCl by weight) and oil solution- filled desiccators and saturated for one year under vacuum to ensure maximum saturation (see Fig. 1). The specimens were removed from the desiccators just before being tested.

3. Experimental procedure

Forty AE compressive strength tests were performed (see Fig. 2(a)) to study the fracture propagation patterns in oil-and brine-saturated reservoir rock samples. The test series was conducted at Monash