ASSESMENT OF LOCALISED DEFORMATON IN SANDSTONES VIA HIGH SPEED NEUTRON TOMOGRAPHY

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Summary: We investigate the application of High Speed Neutron Tomography (HSNT) to sandstones during imbibition tests, which have been carried out at the CONRAD NT instrument at HZB. We aim to track the 4D fluid (herein water) front through specimens with and without laboratory-produced deformation bands. The impact of these deformation features on the flow is discussed through HSNT linked – in some cases – with other non-destructive experimental methods (*e.g.,* Acoustic Emission, x-rays).

1. Introduction

Deformation bands in sandstones have been identified in natural outcrops and have been experimentally studied/replicated at the laboratory scale by many researchers [*e.g.*, 1]. The physical micro-processes that take place during the formation and evolution of shear and compaction bands share similar characteristics but, at the laboratory scale, these micro-processes differ in proportions and order of occurrence in time [2]. These deformation features are characterised by grain rotation, grain fragmentation, grain crushing, and pore loss, depending on the dominant mechanisms, leading to local changes in porosity and presumed permeability. Thus, both shear and compaction bands impact fluid flow, with significant implications for hydrocarbon production in subsurface geological reservoirs and CO_2 disposal into aquifers.

A range of non-destructive advanced experimental methods have already been applied to describe the mechanical response operating during the creation and propagation of both shear and compaction bands, providing an understanding of the spatio-temporal evolution of their properties [2, 3]. The scope of this work - which belongs to a broader project on the application of multi-scale experimental approaches to understand in depth fluid flow within fractured reservoir rocks - is to provide a more concrete conception of the interplay between deformation bands and fluid flow. The focus, herein, is placed on tracking fluid flow in porous sandstones, performing water-imbibition tests on specimens with laboratory-produced deformation bands, using High Speed Neutron Tomography (HSNT). The advantage of using neutrons consist in the high contrast between the rock material and the water, due to the high absorbtion of neutrons by its hydrogen.

Neutron radiography has been previously applied to characterise fluid flow in a shear band [4, 5], whereas x-ray CT has been used during capillary imbibition tests to characterise flow in a compaction band [6]. Here we report the first time that in-situ HSNT is used to characterise the fluid flow front during water imbibition tests in porous media such as sandstones with shear and compaction bands.

2. Experimental Method

Imbibition tests and in-situ HSNT have been performed in the CONRAD Neutron Tomography instrument at the

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HZB [7]. The main challenge of this work has been to find the optimal combination of the scanning conditions to capture the in-situ processes (*i.e.*, the water front movement) without compromising too much the spatial and temporal resolution. HSNT was performed acquiring the projections while the rotation stage was moving, with a constant speed, from 0° to 180° and back. The acquisition time for each of the 300 radiographies was 0.2 sec, which results in a total time of 1 min per tomography. Specimens, wrapped with Teflon tape and placed in a fluorated membrane, were settled in a cup sealed with silicon and fixed at the rotation stage. A small reservoir was connected to the cup through an electro-operated valve so that the supply of water to the cup could be controlled during the experiments. Both image reconstructions and flow front detection and tracking have been achieved by using in-house software (based on ASTRA libraries in the case of reconstructions).

3. Results

HSNT could successfully capture the 4D evolution of the water front during imbibition tests in sandstone specimens with localised deformation. The textural changes, linked to deformation processes within these bands, seem to influence the water path through the volume of the specimen. In particular, deformation bands, appear to rapidly imbibe the water, but in these flow-rate limited experiments, the frontal advance is retarded by the bands. Figure 1a shows compaction bands in one of the specimens, defined by syn-deformation Acoustic Emission (AE) monitoring [3]. A notch, at the mid-height of the specimen, had been previously machined to facilitate the onset of compaction bands during the triaxial compression experiments. Figure 1b shows a volume rendering of the HSNT image when the water has just passed the notch (imbibition tests were carried out post the triaxial compression tests that had been coupled with AE monitoring). Figure 1c shows that compaction bands areas affect the water saturations (light versus dark blue).

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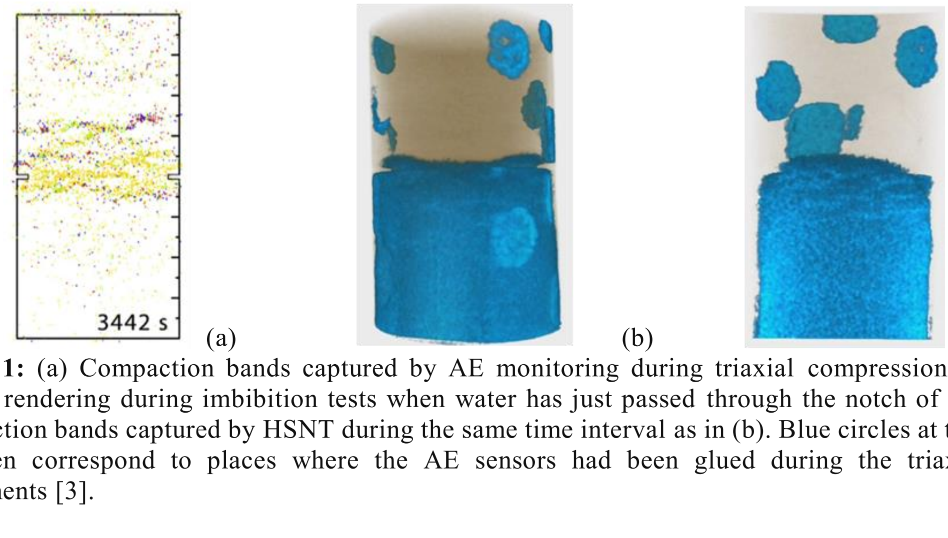

(a) (b) (c)

Figure 1: (a) Compaction bands captured by AE monitoring during triaxial compression tests; (b) HSNT volume rendering during imbibition tests when water has just passed through the notch of the specimen; (c) Compaction bands captured by HSNT during the same time interval as in (b). Blue circles at the mid-top of the specimen correspond to places where the AE sensors had been glued during the triaxial compression experiments [3].