Peer-reviewed Conference Contribution

# Modelling gas fracturing experiments in saturated clay using zero-thickness interface elements

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The injection of gas in a liquid-saturated clay-rich material may lead to the formation of narrow channels or fractures created by the mechanical action of gas pressure. However, the complexity of the mechanical and transport properties of clays, combined with the high compressibility of gases, makes it challenging to understand and address this phenomenon. Gas fracturing can occur in a range of engineered processes, for instance the stimulation of sensitive hydro-carbon reservoirs [1], carbon dioxide injection and storage in subsurface reservoirs [2], pneumatic fracturing for enhanced remediation of contaminated soils [3], or gas transport through natural and engineered clay barriers in geological disposal facilities for radioactive waste [4]. Despite the multiple environmental and economic implications associated with gas fracturing it remains difficult to predict and control due to the lack of fundamental scientific insight.

One of the most challenging aspects of understanding gas-driven cracking in clays is the difficulty in visualising the crack formation in real time. In recent years, a new experimental setup has been proposed by the British Geological Survey, which makes it possible to induce and observe the formation of "two dimensional" cracks in clay-rich low-permeability materials by the injection of gas or water [5,6]. In this setup, a thin layer (~1mm) of clay paste is compressed between a 110 mm diameter sight glass and a steel plate, while it is held laterally in place by a ring filter (Figure 1). Then, gas is injected at the centre of the lower platen at a controlled volumetric rate while the cracks induced are registered by a camera through the sight glass.
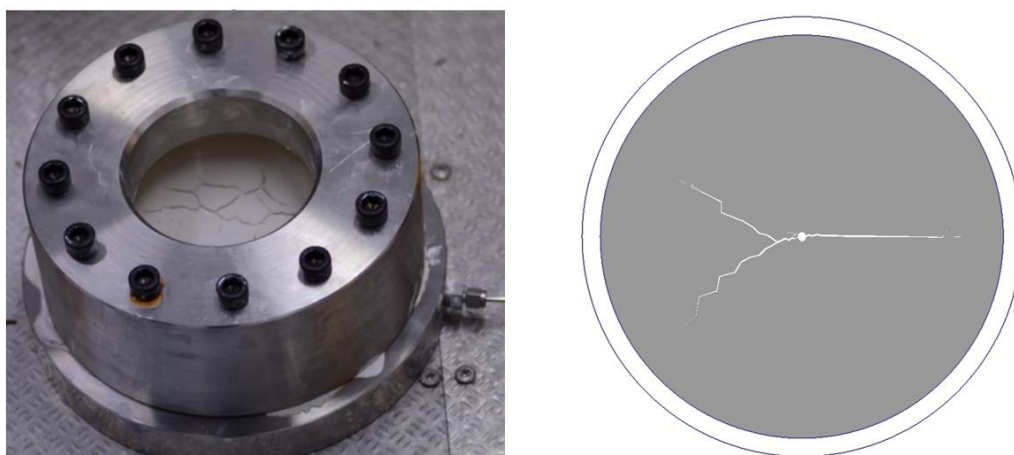


**Figure 1: Experimental setup [6] and numerical simulation.**

In order to aid the interpretation of the results obtained with this new device, the authors have carried out a series of numerical simulations performed with a finite element approach recently published [7], and compared them to experimental data. The model uses a fully coupled Pneumo-Hydro-Mechanical (PHM) formulation in 2D, and is implemented in the code LAGAMINE [8]. Two

different types of finite elements are used: continuum and interface elements. Continuum elements are used to represent the mechanical and flow processes in the bulk clay material and interface elements are used to represent cracks. Interface elements are introduced a priori in between the continuum elements in order to provide potential cracking paths. The model parameters are such that, as long as the interface elements remain closed, they do not have any significant effect on the response of the model.

These simulations required two additional numerical developments. First, since the model is 2D (plane strain), the tangential, frictional stresses developed at top (clay-glass interface) and bottom (clay-steel interface) were introduced as a body force, using an elastoplastic formulation in terms of the in-plane displacements and the out-of-plane stress. Second, a mixed boundary condition was implemented to make it possible to impose a given volumetric gas injection rate as in the experiments.

The simulations show that the model proposed can reproduce the experimental results, providing valuable insights into the factors controlling the onset and propagation of the gas fractures (Figure 1). These insights have the potential to enhance the performance and safety of projects involving gas fracturing processes.

**Contributor statement**

**J.L.:** Conceptualization, Methodology, Software, Validation, Writing – original draft, Funding acquisition. **A.C.D:** Conceptualization, Supervision, Writing – review & editing. **P.J.V.:** Conceptualization, Supervision, Writing – review & editing.

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