LABORATORY X-RAY MICROTOMOGRAPHY OF SAND PROPPANT PACK UNDER STRESS

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Summary: Three-dimensional imaging of sand proppant pack structure was investigated by means of X-ray microtomography (microCT) under stress conditions. An impact on pack conductivity of particular phenomena have been studied in the work. Achieved results support further analysis of a fracture behaviour filled with a studied proppant.

1. INTRODUCTION

Proppant is a granular material (ceramic particles or round-shaped sand) used in oil and gas industry during hydraulic fracturing of the rock [1]. The aim of its application is to prevent the closure of the fracture under natural stress in a rock after termination of the hydraulic fracturing procedure to enable hydrocarbons to reach the production well. Thus, the main properties of concern for a proppant pack are strength and permeability (conductivity). In the industry, the proppant pack permeability at different closure stresses is typically characterized by means of experiments in a conductivity cell [2]. The current study investigated the possibility of deriving these parameters from 3D microCT images of the sand pack structure.

Despite many efforts focused on studies of fluid flow in proppant pack both by academy and industry (e.g. [3]), there are quite a few publications dedicated to its true 3D modelling using microCT data followed by comparison with direct conductivity experiments. In the present work, both imaging and laboratory measurements were conducted with physically the same sand pack samples. Each sample was studied at different confining pressures.

An important outcome from imaging proppant pack under various stresses is the visualization of conductivity degradation with increase of confining pressure. It reveals the associated fundamental processes inside the fracture (destruction of sand particles and rock, proppant embedment in rock media, chemical scale on grains, etc.) and helps to understand the impact of each damage mechanism separately. Further quantification of these phenomena will potentially improve the prediction accuracy of proppant pack behaviour in real fractures under formation conditions.

2. EXPERIMENTAL METHOD

In the work being reported, a sand proppant pack was placed inside the fracture in a rock miniplug sample, so-called split-core approach (see Fig. 1(a)). The diameter of such split-core is 8 mm. The essential point in the study consists in applying in-situ conditions (at least for stress) to a sample. For this purpose, a high-pressure cell compatible with our laboratory microCT system was designed. The cell allows maintaining confining pressure up to 400 bar with a simultaneously ongoing filtration process.

During the study, various types of sand and rock were combined and imaged at different confining pressures (0, 100, 200, and 400 bar). In addition to imaging the sample, a measurement of the sand proppant pack conductivity was performed at each pressure level. Achieved values were compared with results of in-house numerical simulations with DHD method [4] (see Fig. 1(b,c)).

All imaging experiments were performed using laboratory X-ray microCT system SkyScan 1172 (Bruker microCT). The operating parameters of the X-ray tube were 100 kV and 100 μA.

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3. RESULTS

Achieved results show good agreement between numerical and laboratory experiments. Several well-known fracture conductivity damage mechanisms were identified in 3D microCT images (e.g. Fig. 1(d)) and quantitatively characterized (Fig. 1(e)). Further steps consist in correlating proppant/rock properties with observed damage processes, as well as degree of manifestation of each mechanism with total conductivity decrease.

References

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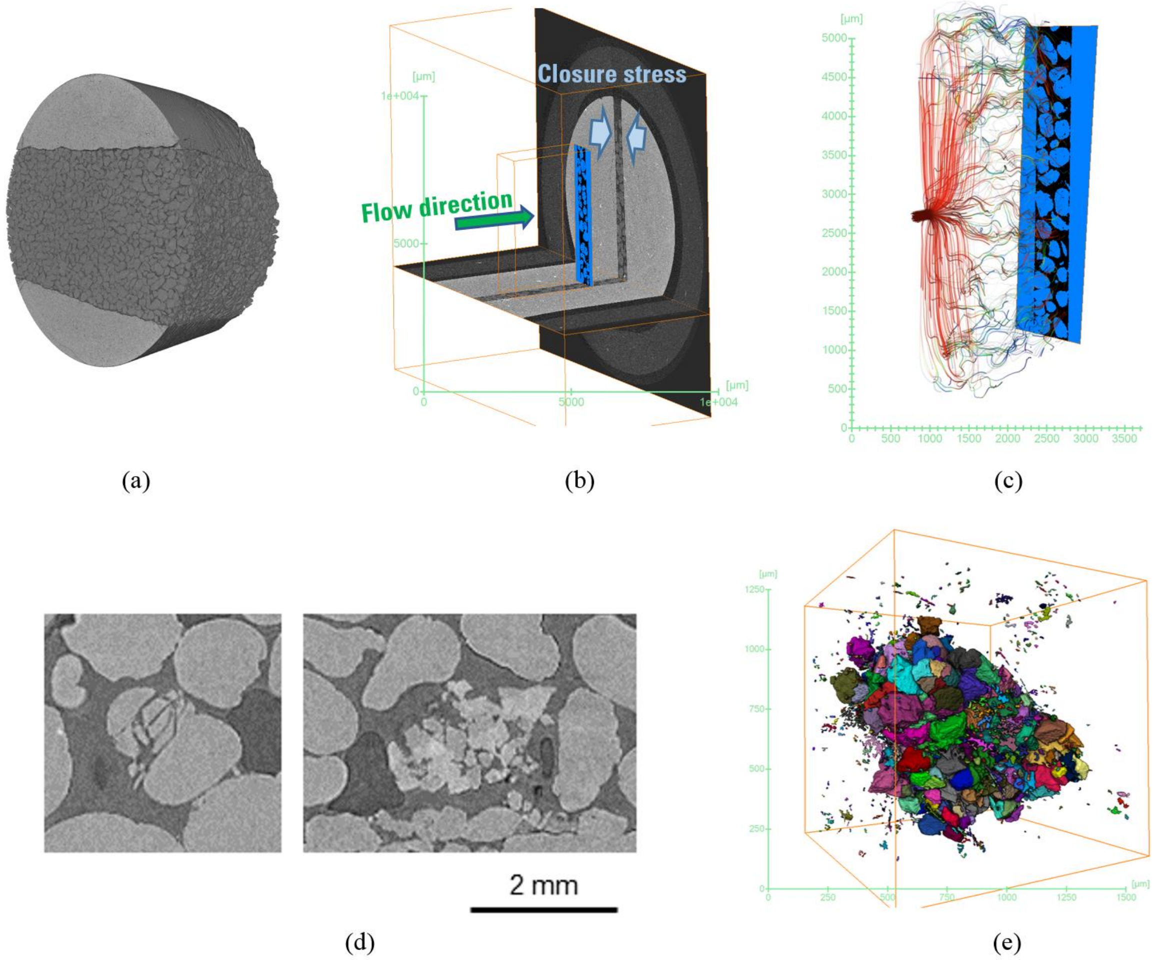

Figure 1: (a) 3D microCT image of a split-core – fractured rock sample filled with a sand proppant pack; (b) synthetic fracture geometry and corresponding computational domain; (c) streamlines for simulated velocity field; (d) examples of damaged sand particles (cracked and popped); (e) segmented fragments of popped sand grain.