# *TOMOGRAPHIC INVESTIGATION OF THE FRACTURE EVOLUTION DURING LOADING OF THE QUASI-BRITTLE SPECIMEN*

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**Summary:** The quasi-brittle specimen behavior was investigated thanks to a newly developed compact four-point bending device devoted for in-situ tomographic measurement. We show that shape of the crack shape can evaluated on the basis of the differential tomography. Similarly, displacement/strain fields and local fracture toughness was analyzed using the digital image correlation tools.

## 1. INTRODUCTION

For the purpose of the 4D micro-CT, a new four-point bending device with very high stiffness and loading precision was designed to allows evaluation of fracture mechanics characteristics of quasi-brittle materials (like stone, concrete etc.) during post-peak softening. Compact design of the device enables its embedding into existing tomographic setups. In contrary to standard arrangements of the bending devices, the specimen is in our four-point bending device oriented vertically. This concept minimizes variation of X-ray attenuation during rotation of the sample and the loading device and allows to maximize possible projection magnification, which is necessary for detailed tomographic investigation of the loaded sample. Detailed description of the device is provided in [1].

During 4D micro-CT procedure (attribute “micro” means that the magnification is high enough to be able to characterize micrometric scale features), one reference CT measurement and one or more consecutive CT measurements during the loading sequence have to be carried out in order to calculate the displacement/strain fields in the deformed sample. Reference CT measurement is typically realized immediately after fixation of the specimen in the loading device. The consecutive measurements are performed several times before reaching the maximal loading force and several times during the softening phase, where FPZ and crack propagation occurs. However, only one CT measurement realized during the softening phase can be enough for evaluation of the fracture toughness, as will be presented in this work.

4D micro-CT reconstruction also allows to apply digital image correlation tools, see [2], on the set of CT volumes. Such approach is applicable if the investigated material has apparent inner structure. It will be shown, that obtained strain/stress fields can serve for calculation of the fracture toughness of the investigated material.

## 2. EXPERIMENTAL

Investigated cylindrical sample of sand-stone with diameter 29 mm was prepared by precise drilling and chevron notch was created in the sample by water-jet cutting. The loading device was for the tomographic measurement installed in the Toratom scanner (European patent CZ28131).

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One reference state and two loading states after reaching the maximal loading force were tomographically scanned and reconstructed with final voxel size reaching 15 μm. An example of the CT slice containing the crack is shown in Figure 1 left.

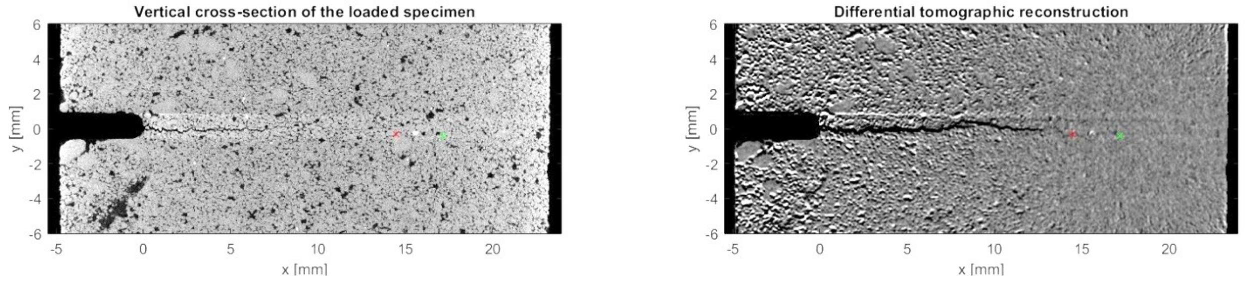


**Figure 1**: Visualization of the vertical slice of the reconstructed micro-CT measurement showing the crack growing from the notch (left). Crack path is hard to identify due to stone microstructure. However, the crack/FPZ shape is well recognizable in the differential CT (right).

Obviously, it is not simple task to identify newly developed FPZ/crack in such a heterogeneous material. However, this obstacle can be overcome by employing differential tomography, where changes in the object are emphasized by differentiation of the actual and the reference tomographic reconstruction, see Figure 1 right. Visualization of the crack growing from the notch is depicted in Figure 2 left (negative ramp filter).

Displacement field can be calculated using digital image correlation tools comparing actual and referential loading state, see Figure 2 right.

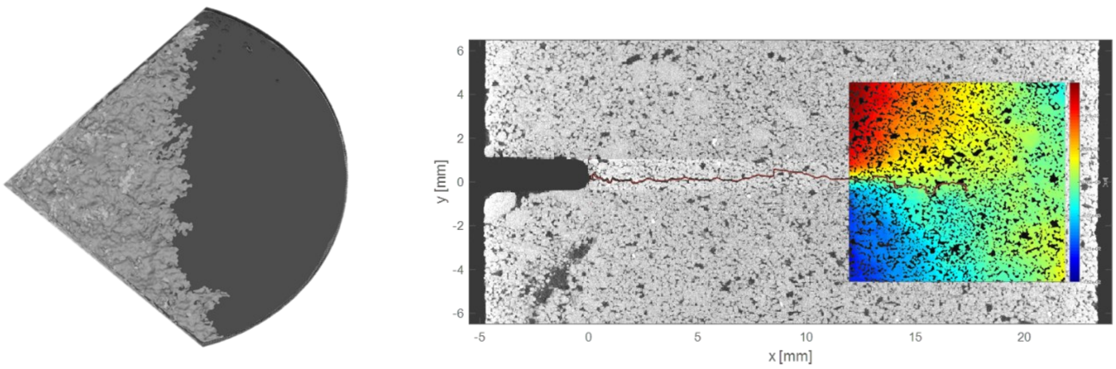


**Figure 2**: Visualization of the crack shape left, calculated displacement field in front of the crack tip right.

## 3. Conclusions

It was shown that newly developed loading device allows to study local fracture processes with high precision even in the quasi brittle materials. CT reconstruction enables to investigate 3D shape of the newly developed crack. Calculated fracture toughness is in good agreement with expected value.

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