Automatic and high-precision microseismic monitoring of progressive failure prior, during, and after tunnel excavation

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Acoustic emission (AE) monitoring is commonly used to inspect the health of a structure continuously. During fracture processes elastic waves of AE are created and emitted, and sensors can capture these waves. The acquired signals can be processed to track and describe the spatio-temporal progression of fractures in solid materials in real-time using quantitative geophysics-based approaches. Typically, these data are processed manually due to the complex nature of the recorded signals mainly caused by heterogeneous medium conditions. This method hasn't found many real-world applications due to its high processing costs of the acquired massive datasets, which may exceed terabytes. Therefore, for use in a structural health monitoring (SHM), an automated methodology that can lower costs while keeping high precision is required.

We discuss the application of a new automated and high-precision AE monitoring algorithm and software called SIMORGH (Momeni et al., 2021a, b) suitable for SHM. The primary software has been created for monitoring laboratory-scale (i.e., cm-size specimen) hydraulic fracturing. The algorithm has been scaled up to work also for heterogeneous media at the meters scale. SIMORGH supports a number of common data formats and can handle both continuous and trigger-based data.

We show some initial results of implementing SIMORGH for microseismic monitoring of rock mass damage evolution around a large-diameter experiment borehole in faulted Opalinus Clay shale in the Mont Terri rock laboratory, Switzerland. The AE data include time periods prior, during, and after borehole drilling and was produced in the frame of the so-called PF experiment (Progressive failure of structurally-controlled overbreaks; Ziegler & Loew, 2020). Eight piezoelectric sensors installed in four boreholes have been used to continually capture data at a sampling rate of 200 kHz, filling up more than 500 GB of memory per day. Active acoustic scanning measurements of body wave velocities showed a transversely isotropic medium with p-wave velocities varying from 2.5 km/s to 3.5 km/s in slow and fast orientations. Adopting the medium information, our software was able to locate over 2000 AE sources automatically for a monitoring period of two weeks, and with a localization precision of 2 mm. Several AEs were also localized manually and show comparable results with those obtained by SIMORGH. If enough processing units are provided, SIMORGH can perform the calculations in parallel and enable real-time SHM with excellent precision on fracture geometry imaging.

References

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