TRANS-SCALE PROPERITES OF PRECURSORY ACCELERATING DEFORMATION IN CATASTROPHIC FAILURE OF UNIAXIALLY COMPRESSED SANDSTONES

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Abstract

The power law acceleration has been validated as an effective method for predicting catastrophic failure time, however, the precursory acceleration distribution in local monitoring signals is still unclear. This paper experimental results to show the variable properties of durations, onset times and critical power law exponents of precursory accelerating deformation with monitoring positions and sizes. Our results declare that precursory strain acceleration at different positions and size windows can provide consistent and stable prediction that agree well with the actual failure time. Our findings suggest that there is an optimal size and monitoring position that present earlier alarm and higher accurate prediction, because of heterogeneity of precursory accelerations in amplitudes and durations.

1. Introduction

Understanding the catastrophic failure process in a brittle rock is critically important for recognizing the driving mechanism of natural hazards such as earthquakes, rock landslides, and volcanic eruptions. Intrinsic defects and damage existing randomly in rock bodies create heterogeneous micro-structures and thus, result in a complex evolution process of failure. This leads to the sample specific properties of catastrophic failure and uncertainties. Identifying a precursory process in a rock sample approaching to failure is a valid method to predict the failure time. However, the precursory accelerating process varies in durations, amplitudes, and the power law exponent. This results in uncertainties of prediction.The open problems include whether precursory acceleration deformation processes emerging at different positions give consistent prediction of failure times, and whether the power law acceleration changes with the monitoring size of average deformation. Highlighting these questions is obviously important for exactly predicting the failure time based on a monitored power law acceleration trend. In this paper, the accelerating deformation behaviors at typical spatial positions are compared based on the evolution process of a surface deformation field in sandstones. The effects of measuring window sizes on the precursory acceleration of deformation are investigated through comparison of the evolution behaviors of average deformations in different calculating window sizes.

2. Results

Sandstone specimens were uniaxially compressed along the direction of height in a testing machine (Instron Model no. 5982) by controlling the crosshead movement at a constant rate of 0.1 mm/min. The surface displacement field was measured by the digital image correlation technique with a sub-pixel accuracy.

In order to compare the change of strains evolving to catastrophic failure at different positions in a specimen, 16 representative positions were selected and numbered as illustrated in Fig. 1a, where positions are indicated with their numbers along column and row. the final linear part in a double logarithmic curve of strain rate (see Fig. 1b), the precursory acceleration of strains at different positions can be well fitted by a power law relationship with time to failure with a consistent critical power law exponents ~1.0 with small fluctuation.

As shown in Figs. 2, the average strains in all measured windows exhibit a similar evolving process with three stages and precursory acceleration. However, the amplitude of average strains decreases in acceleration phases. With the increase of monitoring window sizes, both amplitudes and durations decrease. Here it is of interest to note that the precursory acceleration shows the similar precursory power law acceleration with a consistent power exponent of ~1.0 (see Fig. 2b).

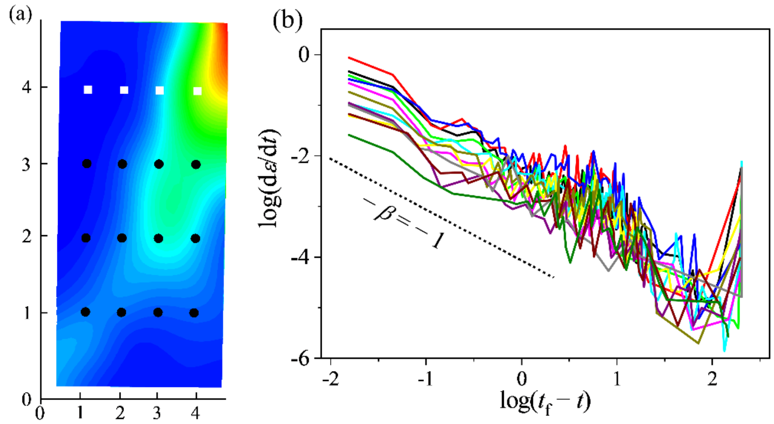

Fig.1 (a) Representative positions to show strain rates. (b) The double logarithmic graph of strain rate versus time-to-failure, in which the straight line has a slope of –1.0.

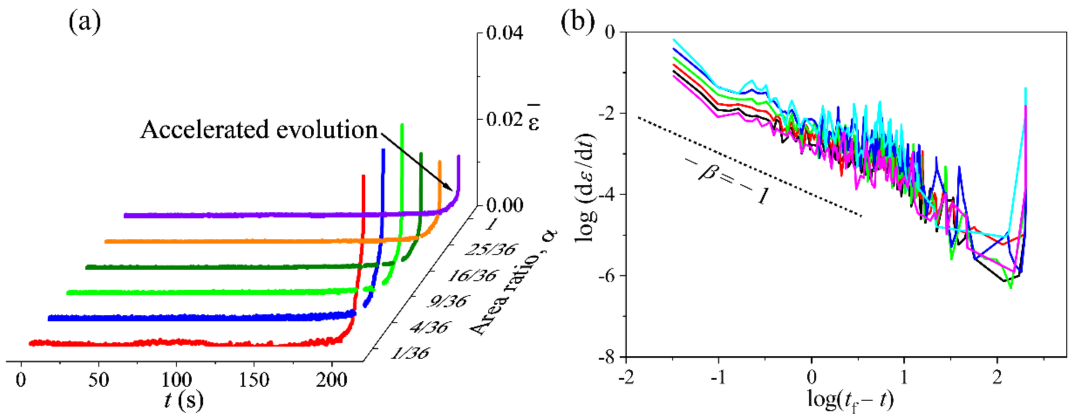

Fig.2 The spatiotemporal evolution of strains in different scales and cross-scale characteristics of critical power-law singularity exponents. α is the area ratio. (a) Mean strains in different sizes. (b) Logarithmic plot of the strain rate versus failure time for six different calculation window widths.

The results show that in the localized zone, strains at a higher strain area are prone to accelerate. The onset of acceleration and magnitude of strain, strain rate and acceleration are directly related to propagation of the localized zone. The onset time of strain acceleration decreases firstly with size, and then increases. Hence, there is an optimize size to calculate the strain for identifying precursory accelerations to produce earlier warning.

3. Conclusions

precursory accelerations of strains exhibit a heterogeneity in amplitudes and durations at different spatial positions. The precursory acceleration and heterogeneity are related to the strain localization. Acceleration of strains occurs firstly at areas where strain localization is nucleated. In the vicinity of failure time, precursory strain acceleration at different positions and size windows can be well described by a power law relationship as time to failure, with the same exponent value.

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