Study on the method of energy evolution of rock under uniaxial compression test

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Abstract. For investigation evolution of energy of rock during the unconfined compression, using same loading rate were carried out uniaxial cycle loading and unloading tests, uniaxial graded loading and unloading tests, and unconfined compression tests. Through the analysis of experimental phenomena shows that the number of cycles has little effect on elastic energy. It indicates that fatigue damage has no effect on elastic energy of rock. Further comparing the elastic energy of the uniaxial cyclic loading and unloading tests and the uniaxial cyclic graded loading and unloading tests, it can be found that their elasticity energy approximately when the loads are the same. Based on above elastic energy studying, can considered that the elastic energy of the rock does not change when the load is greater than or equal to the previous load. Therefore, their elastic energy are the same when the load of unconfined compression are equal to the load of unloading point of the uniaxial graded loading and unloading tests. Based on the above analysis results, the energy real-time evolution before the peak strength of unconfined compression is studied. The method provides a new idea for real-time evolution of energy before the peak strength of rock during the unconfined compression.

1. Introduction

To observe and study rock mechanics problems from the perspective of energy has been paid more attention by the theoretical circles and Engineering. Based on the theory of thermodynamics, energy conversion is the nature of in process of subjected to load, and rock failure is a state instability phenomenon driven by energy [1]. The energy in the rocks includes the elastic energy and the dissipated energy produced by undergo irreversible deformation [2].

In order to better understand and master the energy evolution of rock under the loading, a lot of research work has been done by scholars at home and abroad. Yang et al. [3] conducted conventional triaxial compression tests on marble, studied the triaxial compression deformation failure and energy characteristics of specimens. It turns out that the failure strain energy of rocks increased with the increase of confining pressure, and the relationship between them was linear. All fracture energy of rocks also increased linearly with the increase of confining pressure. Zhang et al. [4] studied the energy evolution of rock under the uniaxial step loading and unloading tests, and found that the elastic energy of red sandstone have no change under difference rate of loading. This engergy study lays a foundation for the study of rock instability conditions. Meng et al. [5] studied energy accumulation in uniaxial cyclic loading and unloading, and the evolution law of acoustic emission during uniaxial cyclic loading was analyzed. Liu jianfeng et al. [6] conducted an experimental study on fine sandstone and silt-grained mudstone under uniaxial compression cyclic load, indicating that the larger the rock density was, the smaller the dissipated energy was. Otherwise, the hysteretic loop area was large and the energy dissipation was also large. Xu jiang et al. [7] conducted cyclic loading tests of sandstone under pore water pressure, and discussed the evolution law of energy absorption and release in the...
process of deformation and damage. Liu et al.\cite{8} based on the strength and deformation relations of rocks under cyclic loading was established a new constitutive model. Huang and Li.\cite{9} studied the conversion of strain energy in triaxial unloading tests on marble. Through studied find that the strain energy before and after the peak has the same law of transformation. The Acoustic Emission\cite{10}, fatigue properties\cite{11}, residual deformation characteristics\cite{12} of rock under the cycle loading conditions were also studied. Energy research has also made great progress in engineering applications. Miao et al.\cite{13} according to the theory of energy accumulation and the stress of surrounding rock, the rock burst was predicted.

Existing research focuses on one particular stage of energy change, such as the total energy before peak strength or after peak strength or the energy evolution under cycle loading. But less studied energy evolution of rock under uniaxial compression test. For investigative the energy evolution in the process of rock unconfined compression tests, using same loading rate were carried out uniaxial cycle loading and unloading tests, uniaxial graded loading and unloading tests, and unconfined compression tests. Through the studing of the rock elastic energy evolution, can considered that when the load of unconfined compression are equal to the load of unloading point of the uniaxial graded loading and unloading, their elastic energy are the same. Based on the above study, energy evolution of rock under uniaxial compression test can be anaalyzed.

2. Method of tests
In this tests, the sandstone with similar internal structure and mechanical properties. The sandstone was processed into standard rock samples with a diameter of 50mm and a height of 100mm. The two ends of the sample are polished with sandpaper to make the flatness of the upper and lower surfaces meet the requirements of the international rock tests standard. The unconfined compression tests, the uniaxial graded loading and unloading tests, and the uniaxial cyclic loading and unloading tests was carried out in the sandstone mechanics tests system of RMT-150B, with a loading rate of 0.5KN/s. In the uniaxial graded loading and unloading tests, because the compaction stage of sandstone is 60KN, so 60KN was selected as the first load. The unconfined compression strength of the sandstones is about 165KN. The uniaxial step loading and unloading tests was 0→60→0→80→0→100→0→120→0→140... until the sandstones break. In the uniaxial cyclic loading and unloading tests, each sandstone specimen use the same load peak value for 21 cycles, and no longer loading after 21 cycles regardless of whether it is damaged or not. The peaks of cyclic loading are 50KN.

3. Analysis of test results
It can be seen from the figure.4 that the unconfined compression strength of sandstone is about 165KN. With initial application of the load, fissure and some pores begin to close, producing an inelastic, concave-upward load-deformation section.

![Figure.1 Unconfined compression tests](image1)

![Figure.2 Uniaxial step loading and unloading tests](image2)
The curve of the sandstone under the uniaxial graded loading condition moves to the right with the increase of number of cycles. The curve to move to the right is due to the new plastic deformation is generated by the increasing of the number of cycles and the increasing of the load. In the uniaxial graded loading process of sandstone, when the load exceeds the maximum load of the previous loading, the curve have same trend with the curve of unconfined compression, which is not affected by the previous repeated loading and unloading.

The cyclic loading and unloading curves shift gradually to the right due to the fatigue damage of rocks and the interface friction between cracks. The speed of the curve moving to the right under uniaxial cyclic loading is lower than that of the graded loading and unloading curve.

Through data processing software, the evolution of elastic energy under uniaxial cyclic loading and unloading condition can be obtained, as shown in Figure.4. Due to fatigue damage and interfacial friction of cracks exist in the process of uniaxial cyclic loading tests of the sandstone, the elastic energy of sandstones has certain fluctuations. But compared with the actual elastic energy, the amplitude of the fluctuation is small.

Therefore, it can be considered that the fatigue damage of the sandstone and interfacial friction of cracks have little influence on the elastic energy, which can be ignored. That is to say, the number of cycles has nothing to do with the elastic energy of the sandstone. Table 1 is average elastic energy of difference number of cycles under uniaxial cyclic loading tests.

4. Analysis of energy during unconfined compression tests
By using the above energy analysis, the elastic energy and dissipation energy of sandstone in unconfined compression tests can be obtained.
As shown in FIG. 5, the elastic energy of sandstone nonlinear growth with the increase of axial load during the unconfined compression tests. The greater the loading is, the greater the elastic energy is. And with the increase of axial load of sandstone, the growth rate of elastic energy also increases.

![Figure 6: Dissipative energy-Axial load of unconfined compression](image)

Figure 6 Dissipative energy-Axial load of unconfined compression

Under unconfined compression tests process, plastic deformation and dissipative energy exist in every stage of sandstone. Dissipated energy tends to increase with the increase of load. Moreover, the growth rate of dissipated energy increases with the increase of load. Near the peak load, the plastic deformation of sandstone increases sharply. Due to plastic deformation of sandstone increases sharply, so requires more dissipative energy. Near the peak load, the growth rate of dissipative energy of sandstone increases sharply. Since the growth rate of dissipated energy and elastic energy increases with the increase of load, the comparison of the growth rate of dissipated energy and elastic energy needs to analyze the evolution of energy proportion.

5. Conclusion

(1) As the cycle numbers increases, the elastic energy of sandstones has certain fluctuations, and the amplitude of the fluctuation is small compared with the actual elastic energy. Therefore, the fatigue damage of the sandstone and interfacial friction of cracks have little influence on the elastic energy of the sandstone under cyclic loading condition, which can be ignored.

(2) By comparing the elastic energy of uniaxial graded loading and unloading tests uniaxial and cyclic loading tests, the elastic energy of uniaxial graded loading and unloading tests is nearly equal that of uniaxial cyclic loading under the same load. During cyclic loading and unloading, the elastic energy of the rock is not affected if the loading is greater than or equal to the previous loading.

(3) Through the study of elastic energy, when the load in the unconfined compression process is equal to the peak load of uniaxial graded loading and unloading tests, their elastic energy are equal.

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