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Study on dynamic characteristics of red sandstone under cyclic impact

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ABSTRACT

In order to study the dynamic characteristics of red sandstone under cyclic impact, the cyclic impact test of red sandstone at the same incident velocity was carried out by E-SHPB test device. Through the analysis and summary of the test data, the influence of cyclic loading times on the dynamic compressive strength of red sandstone and the failure process of red sandstone under the impact of 1000v loading voltage are discussed. The test results show that under the impact of 1000v loading voltage, the peak stress of the specimen decreases linearly with the increase of the number of impacts. The dynamic compressive strength of the specimen under the fifth cyclic impact loading is about 9MPa lower than that under the first impact, and the resistance to deformation is weakened. With the increase of the number of impacts, the cracks in the specimen are continuously generated and expanded, and the specimen is mainly split failure.

KEYWORDS

Cyclic impact; Red sandstone; E-SHPB; Dynamic compressive strength; Characteristics of destruction

1. INTRODUCTION

In underground engineering such as mining and tunnel excavation, safety accidents caused by the instability and failure of surrounding rock are often not caused by a single impact load, but the surrounding rock is subjected to cyclic dynamic disturbances such as blasting and mechanical drilling, and is produced under multiple impact loads. The micro-cracks in the surrounding rock are subjected to multiple loads and then continue to expand, develop and even form through cracks, and then instability occurs. This process can be considered to be caused by dynamic cyclic impact. Therefore, it is of great practical significance to study the mechanical properties and failure characteristics of rock under cyclic impact load for the safety of underground engineering.

At present, the study of damage evolution and energy consumption characteristics of rock under cyclic loading is one of the research hotspots at home and abroad. Xu Jinglong et al. [1] carried out cyclic impact tests on red sandstone specimens under different impact pressures and confining pressures using a SHPB device with a confining pressure device and a nuclear magnetic resonance instrument. The porosity, T2spectrum curve, nuclear magnetic resonance imaging and energy consumption law of the rock after impact were analyzed, and a new damage degree calculation method was proposed. For the problem of dynamic instability and failure of rock under cyclic impact load, many experts and scholars have carried out many discussions. Song et al. [2] used SHPB device to study the failure mode of reef limestone under cyclic impact load, and used LSDYNA numerical simulation software to study the dynamic mechanical properties of reef limestone under three cyclic impact loads.

2. TEST SYSTEM

2.1. Introduction to the Test

In this experiment, a total of three groups of E-SHPB dynamic impact were carried out. The test device combined with ultra-dynamic strain gauge and photoelectric velocimeter to carry out cyclic impact on red sandstone. Among them, the electromagnetic drive Hopkinson experimental technique (E-SHPB)[3] is a new dynamic loading technique developed by combining the electromagnetic drive technique with the Hopkinson experimental device, which replaces the traditional Hopkinson experimental technique by using the air pressure loading method to drive the impact bar to impact the incident bar to generate the stress wave.

The ultra-dynamic strain gauge can record the strain history by strain gauges pasted on the incident bar and the transmission bar, and store it in the form of electrical signals. According to the one-dimensional stress wave propagation theory, the dynamic stress, strain and strain rate of the specimen can be indirectly obtained by the voltage signal collected by the strain gauge. The stress, strain and strain rate of red sandstone can be calculated by experimental stress waveform [4]:

$$\sigma(t) = \frac{AE}{2A_s}[\varepsilon_I(t) + \varepsilon_R(t) + \varepsilon_T(t)] \tag{1}$$

$$\varepsilon(t) = \frac{C}{L_s}\int_0^t [\varepsilon_I(t) - \varepsilon_R(t) - \varepsilon_T(t)]dt \tag{2}$$

$$\dot{\varepsilon}(t) = \frac{C}{L_s}[\varepsilon_I(t) - \varepsilon_R(t) - \varepsilon_T(t)] \tag{3}$$

In the formula, A, E and C are the cross-sectional area, elastic modulus and longitudinal wave velocity of the compression bar, respectively. AS and LS are the cross-sectional area and thickness of the sample, respectively. εI(t), εR(t) and εT(t) are the incident strain, reflected strain and transmitted strain at t, respectively, and t is the duration of stress wave.

In this paper, the dynamic mechanical properties of red sandstone are analyzed by the data obtained from the impact test, and the failure characteristics are explored.

2.2. Test process

In this test, a cylindrical rock mass with a diameter of 50 mm and a height of 25 mm was selected, as shown in Fig.1.

Fig.1 Experimental red sandstone

In the experiment, a square brass sheet with a thickness of 0.3 mm and a width of 15 mm was used as a shock wave shaper between the impact bar and the incident bar. The specimen was placed between the incident bar and the transmission bar closely, and a proper amount of Vaseline was applied to the contact surface between the specimen and the pressure bar to reduce the end face

friction effect between the pressure bar and the contact surface of the specimen. In the cyclic impact test, if the specimen is not broken after one impact, the next impact is carried out under the same impact voltage. After multiple impacts, until the red sandstone specimen produces macroscopic mechanical damage, the test is stopped.

3. ANALYSIS OF TEST RESULTS

The impact mechanical properties of red sandstone with a loading voltage of 1000v were tested in this test. The results of the impact test are shown in Table 1.

Table 1. Data measured by cyclic impact test of red sandstone

numbering	density(kg/m3)	number of physical volumes of strokes (n)	impact velocity (m·s-1)
gh-1	2416.86	5	4.032
gh-2	2427.33	7	4.021
gh-3	2423.65	4	4.045

After the impact test, the most characteristic data and images were screened out. And explore its dynamic characteristics, as shown in Table 2.

Table 2. The dynamic characteristics of gh-1 under cyclic impact

cyclic impact	wave velocity(m·s-1)	peak stress (MPa)	peak strain (με)
1	3125	61.09	6928
2	2976	57.30	7383
3	2841	55.15	5144
4	2717	52.93	6309
5	/	50.41	6774

The stress-strain curve of red sandstone under cyclic impact of 1000v loading voltage is shown in Fig.2.

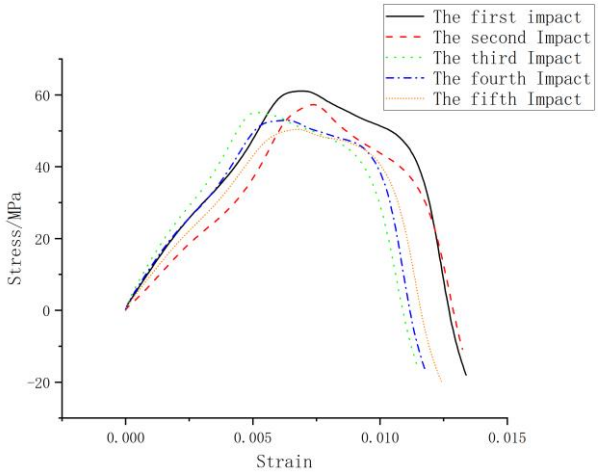
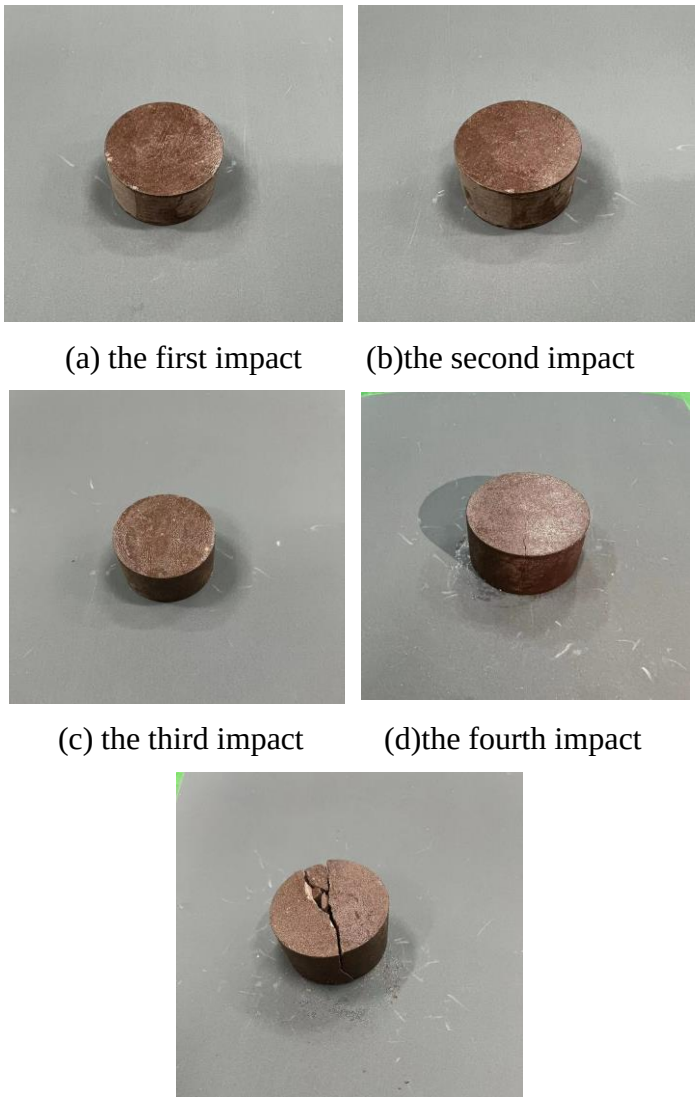


Fig.2 Cyclic impact stress-strain curve of red sandstone

The following is the failure pattern of red sandstone under 1000v cyclic impact load, as shown in Fig.3.



(a) the first impact (b)the second impact

(c) the third impact (d)the fourth impact

(e) the fifth impact

Fig.3 Failure mode of red sandstone under cyclic impact

Fig.3 shows the failure characteristics of red sandstone during the impact of 1000v loading voltage. The failure of the red sandstone specimen gradually evolves along one side of the crack and the overall fracture characteristics appear.

4. CONCLUSION

In this paper, the dynamic mechanical properties of red sandstone materials were studied by using E-SHPB device to carry out cyclic impact on red sandstone specimens. The conclusions are as follows :

(1)With the increase of impact times, the peak stress of red sandstone decreases. Under the 1000v impulse voltage loading, the peak stress of the specimen decreases slowly and then decreases rapidly with the increase of the number of cyclic impacts. The peak strain increases first, then decreases and then continues to increase with the increase of the number of cyclic impacts, and the dynamic compressive strength of red sandstone decreases, and the ability to resist impact deformation is weakened.

(2)Under the impact of 1000v loading voltage, the peak stress of the specimen decreases linearly with the increase of the number of impacts. The dynamic compressive strength of the specimen under the

fifth cyclic impact loading is about 9MPa lower than that under the first impact, and the resistance to deformation is weakened.

(3)With the increase of the number of impacts, the cracks in the specimen are continuously generated and expanded, and the specimen is mainly split failure.

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