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Statistical Damage Simulation Method for Rock Dynamic Deformation Process Based on Nonlinear Dynamic Strength Criterion

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Keywords: Strain Rate, Statistical Damage, Constitutive Model

Abstract: Rock is a typical defective brittle material. The dynamic strain rate of rock has a very important influence on the dynamic deformation process of rock. Considering the non-linear effect of rock dynamic strain rate on rock strength, by improving the existing rock dynamic strength criterion, a non-linear dynamic strength criterion reflecting the effect of strain rate is established. Then, based on the non-linear dynamic strength criterion, by introducing statistical damage theory, the statistical damage constitutive model of rock dynamic deformation process is constructed, and the crank of rock dynamic triaxial test is put forward. Through triaxial compression tests, the whole process of rock non-linear deformation is divided into five stages: Initial compaction stage, linear deformation stage, strain hardening stage, strain softening stage and residual strength stage. In addition, the elastic modulus of some rocks varies with the confined pressure of triaxial tests in the on-line deformation stage. On this basis, statistical damage theory is introduced. Considering the influence of damage threshold and the deformation characteristics of residual strength stage, the analysis method of local deformation of rock matrix is obtained. A statistical damage constitutive model is established to simulate the whole process of rock non-linear deformation. The method of determining model parameters by triaxial compression test curve of rock is proposed. The analysis and discussion of an example show that the method is reasonable and feasible.

1. Introduction

From ancient times to the present, rock plays a vital role in people's lives [1], such as housing construction, underground resource development, water conservancy and hydropower construction, and subway tunnel construction. Especially in recent years, with the rapid development of China's economy, scientific research and practice related to rock mechanics have been greatly developed and achieved remarkable achievements [2]. At the same time, however, there are still many new issues that need to be addressed urgently. As modern production methods change, many areas are related to the dynamic mechanical properties of natural disasters and rocks under impact loads, such as tunnel excavation, mining, conventional explosions and nuclear explosion protection projects, as well as landslides, earthquakes, rock bursts and others. How to consider the dynamic deformation characteristics of rock and develop the simulation method of rock deformation process has become the core of studying the dynamic constitutive relation of rock, which is the starting point of this paper [3].

It can be said that, to a certain extent, the process by which humans use rocks to make better use of rocks is also the development process of human civilization. Mineral aggregates formed by combining one or more diagenetic minerals by certain geological processes. As a natural substance, rock has unique physical properties such as density, water absorption, softening and mechanical properties [4]. In addition, there are many kinds of rocks that make up the main materials of the earth's crust and mantle. In terms of its composition, rocks may be composed of minerals called a single ore (for example, pure marble composed of calcite minerals); they may also be composed of many different minerals, called composite ores (for example, granite from feldspar and quartz minerals) Composition); they may also consist of mineral debris called clastic rocks (such as volcanic clastic rocks). The properties of various minerals vary widely and the way rocks are formed is different, which makes the properties of different types of rocks different. The formation of rocks can be divided into three types: igneous rocks, sedimentary rocks and metamorphic rocks, which can be divided into eruptive rocks and intrusive rocks. Sedimentary rocks can be divided into broken shoulder rocks. Clay rocks, chemical and biochemical rocks and metamorphic rocks can be divided into physical rocks, massive rocks and tectonic fracture rocks [5].

Some of the mechanics of rock materials have similar characteristics. Some early scholars have established some constitutive relations suitable for geotechnical properties in rock research. The classical elastoplastic theory of solid mechanics is the theoretical basis of these constitutive models [6]. According to the basic theory of the plastic constitutive model of early metal materials, further development and consolidation. It is precisely because these models can reflect rock materials to some extent. Some obvious mechanical properties and their theoretical basis are relatively mature. Therefore, this rock mechanics constitutive model was widely accepted by geotechnical engineers on a large scale in the early stage. The method is theoretically rigorous and is widely used in geotechnical engineering. Based on the viscoplastic theory, a new dynamic statistical damage constitutive model for rock dynamic deformation simulation is established. It overcomes the shortcomings of using dynamic strain to directly and accurately describe the evolution process of rock damage, and establishes a damage model to better describe the mechanical mechanism of rock damage. Therefore, compared with the similar model described above, the model has obvious advantages, but there are still some limitations. First, since the dynamic stress of rock is considered to be the superposition of static stress and inertial force caused by rock dynamic characteristics, inertial force is only related to dynamic strain rate, and dynamic strain rate is independent of rock stress [7-10].

The dynamic stress of rock during dynamic deformation always includes the inertial force caused by the strain rate. In other words, even if the rock is not subjected to load, the dynamic stress of the rock is not zero and the strain rate is large. Even if the strain is zero, the difference between the dynamic stress and the actual phase is large, which is obviously opposite to the actual position. Secondly, the rock strength criterion used to establish the dynamic statistical damage constitutive model is the static strength criterion, which cannot reflect the dynamic change of rock. For the above two reasons, the rock dynamic statistical damage constitutive model can only simulate low load or low dynamic strain rate. The dynamic deformation process of the lower rock cannot accurately reflect the dynamic deformation characteristics of the rock at high loading speed. However, in any case, the research method provides a feasible research method and method for the simulation of rock dynamic deformation process. As long as the effect of strain rate on the dynamic deformation performance of rock can be fully improved, dynamic deformation of rock may occur. The process simulation method has been significantly improved. Therefore, this paper considers the dynamic deformation characteristics of rock under high strain rate. By discussing the dynamic strength criteria of rock suitable for different strain rates, including low strain rate and high strain rate, the statistical damage theory is introduced into the rock dynamic deformation process. In order to improve the theory and method of rock dynamic deformation simulation, a dynamic statistical damage constitutive model for rock with high and low dynamic strain rate conditions is proposed.

2. Proposed Method

2.1. Study on Rock Strength Criteria

(1) Overview of the rock

Rocks are geological raw materials and can be divided into karst, sedimentary rocks and metamorphic rocks. Rock mechanics is the study of the force field of rocks in the surrounding physical environment. In short, the study of rock stress and rock deformation, failure law and engineering stability is a branch of rock solid mechanics. Although domestic and foreign scholars have conducted in-depth theoretical and experimental research on rock, there are still some problems with existing research results. It is mainly reflected in the following aspects: the existing rock constitutive model is difficult to reflect the cause of the failure of the yield point of its characteristic rock material. After the initial stage of compaction, the internal voids of the rock gradually close, only when the stress or deformation of the rock reaches a certain value, the so-called damage threshold problem. Since the rock inevitably contains initial voids, cracks and other voids, volume compression will occur during the initial stages of loading. In addition, when the rock is loaded to a certain level of stress, due to rock failure, there will be defects in the rock, new voids, cracks and other voids will be formed, and volume expansion will occur in the rock. At present, there are three methods for studying rock constitutive models, namely elastoplastic theory. The damage theory and the traditional solid mechanics experience fitting method reflect the deformation characteristics before the failure. The simulation of the deformation process after the failure, that is, the simulation after the peak, is It's totally different, especially in the case of failure. It does not reflect the deformation characteristics of the residual strength stage after rock failure, nor can it consider the loading speed or loading speed. Due to the influence of strain rate, the existing rock constitutive model lacks the study of the dynamic deformation process of rock, namely dynamic deformation.

The simulation method for establishing rock deformation process under dynamic load is discussed. However, the existing research results still have some shortcomings, such as the uncertainty of the physical meaning of the parameters and the simplicity of the stress state. At present, the understanding of the mechanical mechanism, transition conditions and rock transformation characteristics of the hardening is not enough. Through the triaxial test, the problem of the transformation of rock strain hardening characteristics is discussed, and the critical stress ratio of the brittle ductile transition of rock is calculated. Therefore, the mechanical mechanism of the strain hardening characteristic transformation of rock should be further explored, and the rock response reflecting the external conditions and physical and mechanical properties of the rock itself should be established. The transition conditions of softening and hardening properties deepen the understanding of its mechanical mechanism. Due to the problems and deficiencies in the research of rock constitutive model, it is necessary to carry out in-depth study on the whole process simulation of rock deformation and failure, and establish the threshold and volume characteristics reflecting rock damage. Changes in rock deformation (ie volume compression and expansion) and residual strength after rock peaking. The mechanism and deformation of rock strain hardening were studied to establish the strain-hardening characteristics of rock and improve the strain hardening characteristics of rock.

Since the purpose of this study is to introduce statistical damage theory and study the dynamic deformation process of rock under complex stress state simulation method, the key of this method is to establish a rock damage evolution model based on rock strength criterion, and the rock strength is based on rock stress. The dynamic characteristics of rock are closely related. The dynamic strength of rock has obvious nonlinear relationship with loading speed or dynamic strain rate. The linear static strength criterion cannot reflect the dynamic damage mechanism of rock. Therefore, in order to use statistical damage to establish rock constitutive model the theory can better simulate the dynamic deformation process of rock. It is necessary to study the dynamic strength criterion of rock to establish the dynamic strength criterion of rock suitable for different loading speed or strain rate. Based on the existing research, reasonable rock dynamic strength standards are discussed.

(2) Traditional rock strength theory

The Hoek-Brown Code is one of the most widely used standards. It not only considers the influence of rock mass strength, structural plane strength, block structure and other factors, but also reflects the nonlinear failure characteristics of the block. In addition, it takes into account the weak stress in the Mohr-Coulomb strength criterion. This criterion describes the failure mechanism of the rock mass under some conditions after the rock is damaged. Therefore, it is more in line with the characteristics of rock damage. Although the standard is a non-linear strength criterion, the triaxial strength of geotechnical engineering evaluation is very different from the measured intensity data under high stress conditions. In addition, subjective factors have a significant impact on the determination of standard parameters. The Hoek-Brown criterion is a measure of the strength of rock materials. The Hoek-Brown criterion is expressed as follows:

$$\frac{\sigma_1}{\sigma_c} = \frac{\sigma_3}{\sigma_c} + \left(m \frac{\sigma_3}{\sigma_c} + s \right)^{\frac{1}{2}} \tag{1}$$

In the above formula, σ_1 is the maximum principal stress of rock failure; σ_3 is the minimum principal stress of rock failure; σ_c is the uniaxial compressive strength of rock; m is a constant related to rock properties. s is the degree of damage to the rock before applying σ_1 and σ_3. For intact rock, take 1 for s.

(3) Theoretical study on constitutive relation of rock

L. Muller performed a uniaxial compression test on various rocks on the test machine. The stress-strain curves of rocks can be divided into six categories. As shown in Figure 1(the picture comes from the network, http:www.baidu.com)

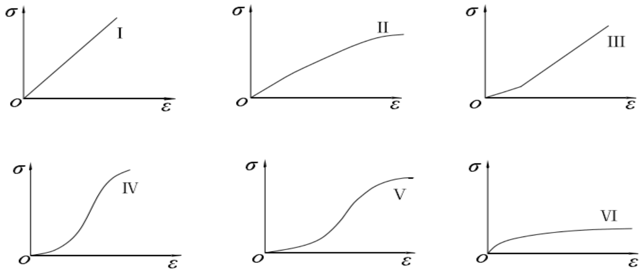

Figure 1. Rock stress and strain curve

Type I: The stress-strain curve approximates a straight line, and the stress-strain curve does not bend significantly until the sample suddenly fails. Its deformation characteristics are linear elastic deformation. The diabase, quartzite, etc. are very hard. Type II: The stress-strain curve starts with a straight line. As the stress increases, the curve begins to bend downward until the sample is destroyed. The slope of the curve is proportional to the stress, and its deformation characteristic is elastoplastic deformation. Soft but compact rocks such as tuff, siltstone and limestone have this deformation characteristic. Type III: The stress-strain curve is concave at the beginning and becomes a straight line as the stress increases until a certain value is reached. This deformation is characterized by elastoplastic deformation. Hard rock with micro-fractures and pores, such as sandstone and granite, has this deformation characteristic. In the initial stage, this is due to the compaction of microcracks and voids. Type IV: The stress-strain curve is S-shaped, the middle straight section is long and steep, and the curved section at both ends is relatively short. In general, dense and hard metamorphic rocks such as gneiss and marble have such deformation characteristics. V-shaped: The stress-strain curve is also S-shaped, but unlike the IV shape, the slope of the straight line is relatively small, the length is relatively short, and the curves at both ends are relatively long. Generally, plastic-elastic-plastic deformation occurs when high-compression rocks (such as gneiss) are subjected to pressure perpendicular to the surface of the blade. Type VI: At the beginning, the stress-strain curve is a straight line segment, then the inelastic portion of the curve appears and the creep is continuous. The deformation characteristics of rock salt belong to this category, and some weak rocks have similar deformation characteristics.

Firstly, since the static stress and dynamic stress of rock are regarded as the model of rock dynamic characteristics caused by the superposition of inertial force, the inertial force is only related to the dynamic strain rate, and is independent of the rock size caused by the stress. In the model simulating the dynamic deformation process of rock, the dynamic stress of the rock always contains the inertial force caused by the strain rate. Even if the rock is not affected by the load, the dynamic stress of the rock is not zero, and the strain rate is larger, even when the dynamic strain is 0. The maximum stress and maximum difference are also obviously opposite to the actual situation. Secondly, the rock strength criterion used for establishing the dynamic statistical damage constitutive model is the static strength criterion, so it cannot reflect the dynamic characteristics of the rock. The dynamic change in its intensity. Based on the above two reasons, the dynamic statistical damage constitutive model of rock can only simulate the dynamic deformation process of rock under low loading speed or low dynamic strain rate, but cannot accurately reflect the dynamic deformation characteristics of rock. High loading speed or high strain rate. However, no matter how the research method provides feasible research ideas and methods for the dynamic deformation process of rock, as long as the influence of high strain rate on the dynamic deformation of rock can be fully considered, the rock dynamic characteristics can be improved. The core of this paper is the improvement of the simulation process of the deformation process.

The uniaxial compression test is used to explore the most basic and most commonly used experimental methods for rock mechanical properties. It is widely used in engineering-related rock mechanics research. The equipment is simple and the principle is clear. It can be used to study many physical and mechanical properties such as rock expansion, wave velocity and conductivity. For the study of rock deformation characteristics, cylindrical specimens (such as core drilling specimens) are usually processed to a diameter of 5 cm and a height of 10 cm. The ends are smooth and the side is equipped with a resistance strain gauge to facilitate deformation measurement. The sample was axially compressed by a press. The axial and lateral deformation of the sample was measured at each pressure. Based on the results of rock uniaxial compression tests, the relationship between stress and strain is discussed. For some rock materials, the linearity of the stress-strain curve is close to a straight line and can be approximated as linear elasticity. The stress-strain ratio is commonly referred to as the elastic modulus of rock and is recorded as E. The stress-strain relationship can be expressed as:

$$\sigma = \mathrm{E}\varepsilon \tag{2}$$

For nonlinear elastic rock, the stress-strain relationship is in the form of a curve, and the stress path of the rock material does not change during loading and unloading. Due to the stress-strain relationship, there is no single modulus. The modulus of a point can be divided into a tangent modulus (E_t) and a secant modulus (E_s):

$$\mathrm{E}_t = \frac{d\sigma}{d\varepsilon} \tag{3}$$

$$\mathrm{E}_s = \frac{\sigma}{\varepsilon} \tag{4}$$

The ratio of the transverse strain ε_d to the longitudinal strain ε_L of the rock is called the Poisson's ratio. As shown below, the rock Poisson's ratio μ is often taken as a prime number when the elasticity changes, if the Poisson's ratio and stress are exceeded once the maximum limit of the rock is exceeded. The positive proportional relationship, that is, becomes larger as the stress becomes larger (μ=0.5).

$$\mu = -\frac{\varepsilon_d}{\varepsilon_L} \tag{5}$$

For rocks in actual engineering, they are not only subjected to stress in one direction but also to stress in a three-dimensional stress state. Therefore, it is more important and practical to conduct experimental research on rock under three-dimensional stress state. The deformation and strength properties of the rock are usually passed through a three-dimensional stress state. According to the different stress states of the rock specimen in the triaxial test, the triaxial test can be divided into two types: the conventional triaxial test and the true triaxial test. The so-called conventional triaxial test means that the stress state of the rock sample is always $\sigma_1 > \sigma_2 = \sigma_3 > 0$ during the test, which is called the ordinary triaxial test. The true triaxial test refers to the stress state of the rock sample during the test is $\sigma_1 > \sigma_2 > \sigma_3 > 0$, also known as the unequal pressure triaxial test. The stress in the axial direction of the device on the specimen is σ_1, the pressure in the pressure chamber is σ_3, and the axial strain is ε_1. The elastic modulus of the device is calculated by:

$$E = \frac{\sigma_1 - 2\mu\sigma_3}{\varepsilon_1} \tag{6}$$

If lateral strain ε_3 is obtained, let $\lambda = \varepsilon_3/\varepsilon_1$, then the Poisson's ratio is as follows:

$$\mu = \frac{\lambda\sigma_1 - \sigma_3}{\sigma_3(2\lambda - 1) - \sigma_1} \tag{7}$$

2.2. Rock Statistical Damage Simulation

Most rock-forming minerals can be considered linear elastomers. Because the rock contains many minerals, its internal structure has various defects, so the deformation characteristics of the rock under external load are different from those of diagenetic minerals. Describe the deformation characteristics of rock by using generalized Hooke's law and elastic constants is not enough for actual engineering rock. Inelastic deformation during rock deformation, such as joint intercalation, fracture, etc., makes the deformation of the rock not fully recovered after unloading. Therefore, by compressing a rock sample having a certain shape and proportion with a pressure tester, a stress-strain relationship between load and deformation can be obtained. Due to the low stiffness of the conventional flexible testing machine, the rock sample itself undergoes great deformation during compression and absorbs a large amount of energy.

After the successful development of the servo machine and the rigid press, the deformation characteristics of the rock material in the post-peak period were studied. Prior to this, the deformation characteristics of the rock were described by the deformation characteristics of the front zone. It is believed that the strength of the rock mass is the peak stress. When the stress exceeds the peak value, the rock mass will be completely destroyed because the rock mass cannot bear the load. But this obviously does not match the actual situation. As the rock has experienced geological forces and various external forces during the long-term geological period, some rocks have been destroyed many times. There are many different types of joints and cracks in the rock, which are no longer intact rocks. Scientific experimental research and field practice show that even if the rock mass is deformed and broken, it still has a certain bearing capacity, especially in the case of lateral confining pressure. J. Lemaitre proposed the strain equivalent assumption. This assumption is based on the fact that the damage factor can be considered and the constitutive equation of the material is not expected to be too complicated. The core assumption is that the strain ε caused by the macroscopic stress σ on the damaged material is equivalent to the strain ε' caused by the effective force σ'. Namely: $\varepsilon' = \varepsilon$. If the damage factor D is defined as the volume ratio of the damaged material to the entire material in the figure, the effective strain σ' acting on the damaged material produces an effective strain of ε', and the actual strain generated by the actual stress σ acts on the damaged material to be ε. Considering the three-dimensional stress state, the Lemaitre strain equivalent assumption can be used. Rock damage model:

$$\begin{cases} \dfrac{\sigma'}{1-D} = E\varepsilon' \\ \sigma = E\varepsilon \\ \sigma_i = \sigma_i'(1-D) \end{cases} \tag{8}$$

The damage model of the rock softening deformation process is:

$$\sigma_i = E\varepsilon_i(1-D) + \mu(\sigma_j + \sigma_k) \tag{9}$$

One of the more successful methods for establishing rock damage evolution models is to establish a rock damage evolution model using statistical damage theory. The key is to reasonably measure the strength of rock microelements. The measurement method based on the Mohr-Coulomb failure criterion F can be described as:

$$F = (1 - \sin\varphi_f)\sigma_1' - (1 + \sin\varphi_f)\sigma_3' = 2c_f \cos\varphi_f \tag{10}$$

c_f is the cohesive force of the rock after it has been destroyed, and φ_f is the angle of friction when the rock reaches the damage. Although the rock micro-element strength measurement method described above is more reasonable than the method proposed by previous researchers, there are still some unreasonable points. First, the rock damage evolution model established by this method shows that rock damage occurs as long as the rock is deformed or subjected to load. In fact, rock damage is not the case, but only when it changes, assuming that the rock micro-element strength obeys the Weibull distribution, the rock statistical damage evolution model can be established to consider the influence of the threshold. The expression is as follows:

$$D = \begin{cases} 1 - \exp\left[-\left(\dfrac{F}{F_0}\right)^{m}\right] & F \geq 0 \\ 0 & F < 0 \end{cases} \tag{11}$$

We can sort out that when F < 0, the damage factor D of the rock is always zero, that is, the rock is not damaged and belongs to a linear elastic state; at this time, the rock material is in a state of continuous damage, and damage is taken in the interval. Variable or damage factor. At this time, the damage variable is directly related to the stress state of the rock, because the F= 0 rock yield criterion indicates that the starting point of rock damage is the yield point, reflecting the reasonable starting point of rock damage. This is consistent with the description of the rock failure characteristics described above.

The damage constitutive model and the determination of the parameters are as follows for the rock damage constitutive model:

$$\sigma_1 = \begin{cases} E\varepsilon_1 \exp\left[-\left(\dfrac{F}{F_0}\right)^{m}\right] + \mu(\sigma_2 + \sigma_3) & F \geq 0 \\ E\varepsilon_1 + \mu(\sigma_2 + \sigma_3) & F < 0 \end{cases} \tag{12}$$

Triaxial and uniaxial tests of rock are routine tests to determine the physical and mechanical properties of the rock. The method for determining parameters by introducing a triaxial stress-strain curve is given below. Under different confining pressures, the stress-strain curve peaks correspond to stresses and strains of σ_{sc} and ε_{sc}, respectively, and the corresponding rock micro-element strength is F_{se}. Obviously, when the rock reaches the damage, the test curve should meet the following geometric conditions:

$$\begin{aligned} \varepsilon_1 &= \varepsilon_{sc} \\ \sigma_1 &= \sigma_{sc} \\ \frac{d\sigma}{d\varepsilon} &= 0 \end{aligned} \tag{13}$$

Brought into the rock damage constitutive model to get:

$$\sigma_{sc} = E\varepsilon_{sc} \exp\left[-\left(\frac{F_{sc}}{F_0}\right)^{'''}\right] + \mu(\sigma_2 + \sigma_3) \tag{14}$$

3. Experiments

3.1. Experimental Data Set

In this paper, the statistical damage constitutive model is established, and the whole process of nonlinear deformation of rock is simulated. The method of determining relevant parameters is given. In order to verify the rationality and feasibility of the model, an example is introduced to illustrate the feasibility of the model. Experimental data for the Aaron triaxial SHPB device is cited.

3.2. Image Processing Analysis

Geokit is a powerful petrochemical mapping software. Geochemical parameters and charts are often used as an effective tool for geological and geochemical research. Using these graphs and parameters, we can classify rocks, distinguish the genesis of rocks and sediments, distinguish the tectonic setting, and study the history of geological evolution. Discriminant maps of the tectonic environment (such as trace elements in Pearce's granite) and some empirical discriminants are given. The principles of these illustrations and parameter calculations are scattered among various documents. On the one hand, it is inconvenient for users to frequently quote. On the other hand, manual mapping can be labor intensive and not accurate enough. RockPlot is a new geochemical charting software for rock, minerals, geochemistry and other earth sciences that helps geoscientists get rid of complex data processing and image production. The software is small in size and fast in operation, and can effectively complete rock geochemical maps and parameter calculations. It can edit and modify charts in real time, support vector and bitmap format output, and provide encyclopedias for quick learning of charts and calculations. Update graphics and calculations over a network connection server to keep graphics and calculations up-to-date and complete.

4. Discussion

4.1. Dynamic Deformation of Rock

Considering the influence of rock damage threshold, a new statistical model of rock damage evolution is established, and the influence of damage threshold can be considered. The model shows that rock damage not only has a damage threshold, but also is directly related to the stress state at the time of rock damage. In the stress state, the starting point of the rock being destroyed is different. Rock damage occurs only when the microelement strength is greater than zero, and when the microelement strength is less than zero, the deformation of the rock material is linearly elastic, and the failure variable is constant to zero. In order to verify the rationality of the simulation method of the rock dynamic deformation process, the experimental data of the Aaron triaxial SHPB device was cited. Through analysis, the conventional rock mechanics parameters of rock under different loading strain rates can be obtained.As shown in table 1,Figure 2, Figure 3, Figure 4.

Table 1. Conventional rock mechanics parameters

$d\varepsilon_1 / dt / s^{-1}$	E / Gpa	C / Mpa	φ / (°)
0.00005	21.6	24.37	37.9
100	21.6	33.54	41.8
1000	21.6	32.27	47.6

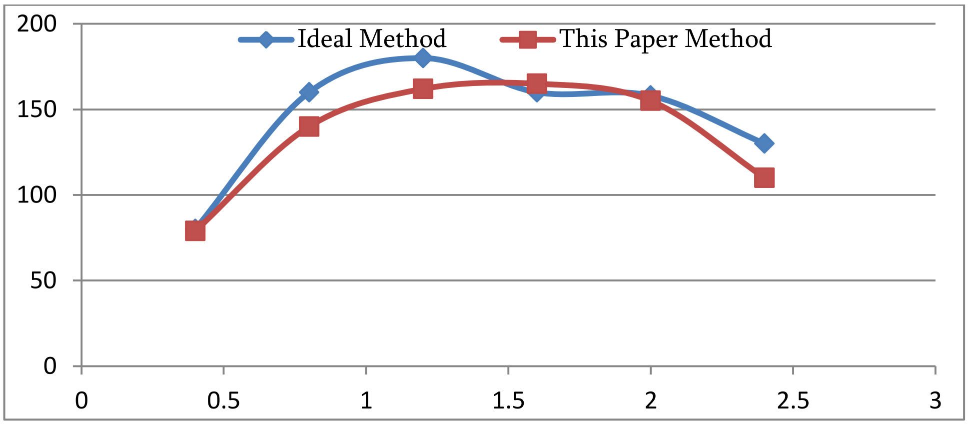

Figure 2. The first parameter experiment results

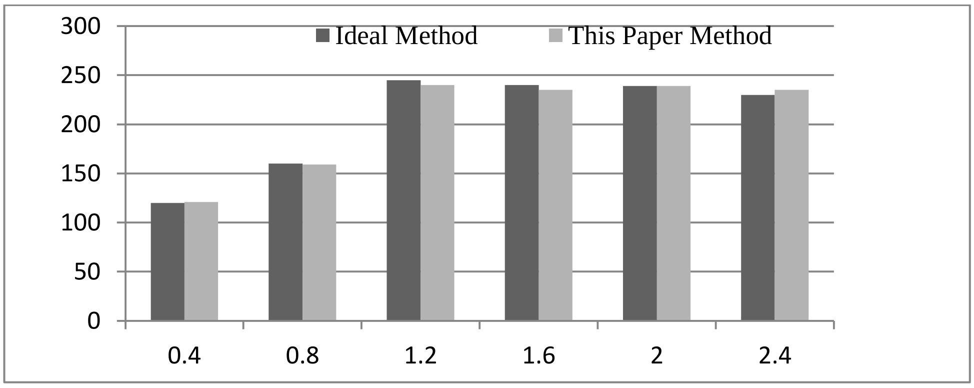

Figure 3. The second parameter experiment results

Based on the damage mechanics and statistical theory, the damage statistical variables based on the Weibull distribution are determined from the microscopic and statistical perspectives. The statistical damage model is established and the specific calculation method of the model parameters is given. And compared with the experimental results. Based on the statistical damage model, the damage evolution law of rock under impact load is analyzed. The calculation method of the model parameters in this paper can be directly obtained from the measured constitutive curve, which avoids the ambiguity of the physical meaning and the large error of the model parameters due to the method of fitting the parameters. On this basis, the mechanical mechanism of rock deformation and the characteristics of the whole process are discussed. The relationship between rock deformation and local deformation of rock groups is established. The deformation analysis and deformation analysis methods of rock matrix rocks are discussed respectively, and the rock deformation analysis model is finally obtained. By discussing the dynamic strength criteria of rock suitable for different strain rates, including low strain rate and high strain rate, the statistical damage theory is introduced into the rock dynamic deformation process. In order to improve the theory and method of rock dynamic deformation simulation, a dynamic statistical damage constitutive model for rock with high or low dynamic strain rate conditions is proposed.

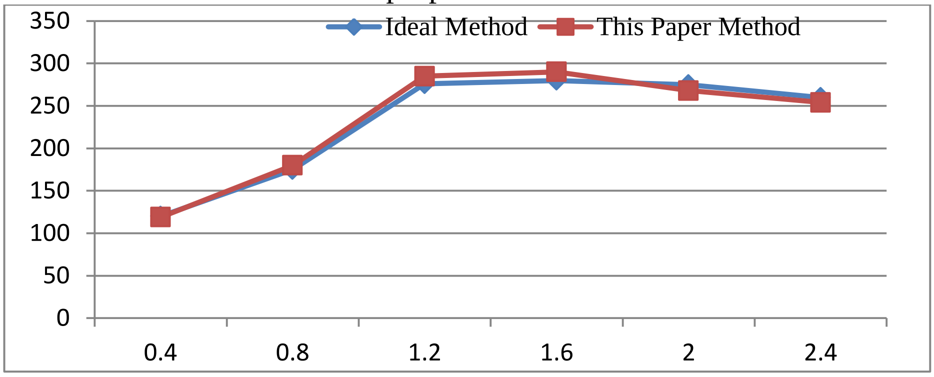

Figure 4. The third parameter experiment results

4.2. Analysis of Experimental Data

Considering that the rock sample is a complete rock, the approximate value is 0000. According to the model, when the confining pressure is 111 and 20 MPa, respectively, it can be seen from the following figure that the curve under ideal conditions is basically consistent with the curve under experimental operation. It can be seen that under the same confining pressure, the dynamic strength of rock increases with the increase of loading speed or strain rate. At the same loading speed or strain rate, the dynamic strength of rock increases with the increase of confining pressure. The above rules are obviously consistent with the actual situation, and also illustrate the rationality of the model in this chapter.As shown in Figure 5, Figure 6.

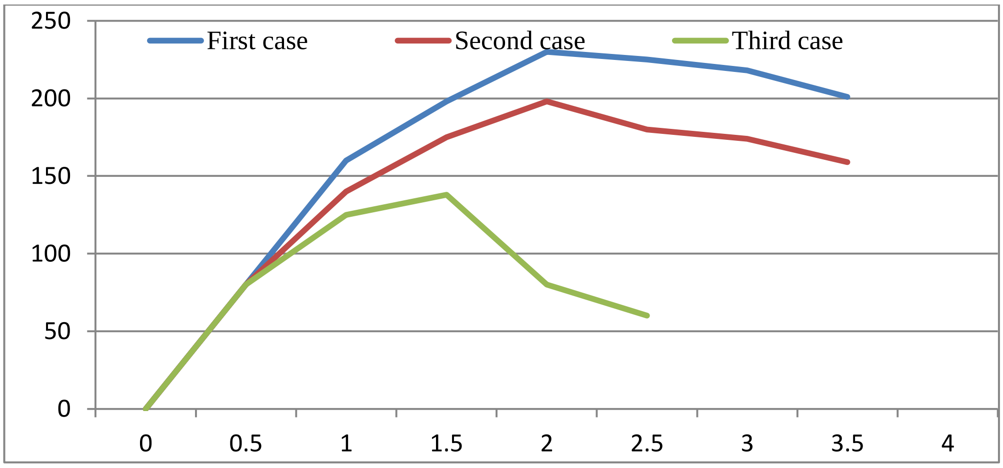

Figure 5. Stress and stress theory 1

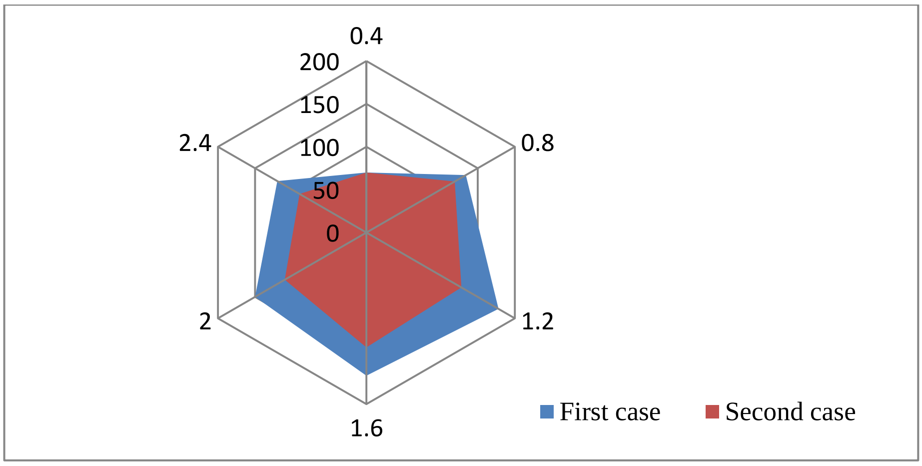

Figure 6. Stress and stress theory 2

5. Conclusion

(1) The dynamic strain rate of rock has a very important influence on the dynamic deformation process of rock. Therefore, firstly, the nonlinear dynamic influence of rock dynamic strain rate on rock strength is considered. By improving the existing rock dynamic strength criterion, a nonlinear dynamic strength criterion reflecting the influence of strain rate is established. Then, based on the nonlinear dynamic strength criterion, the statistical damage theory is introduced to establish the rock dynamic statistical damage constitutive model, and the rock dynamic triaxial test crank is proposed.

(2) Through the triaxial compression test, the whole process of nonlinear deformation of rock is divided into five stages: initial compaction stage, linear deformation stage, strain hardening stage, strain softening stage and residual strength stage. In addition, during the online deformation phase, the elastic modulus of some rocks will vary with the confining pressure of the triaxial test. In order to establish the simulation method of the whole process of rock nonlinear deformation, this paper deeply analyzes the mechanical properties of different types of rock. On this basis, the mechanical mechanism of rock deformation and the characteristics of the whole process are discussed. The relationship between rock deformation and local deformation of rock groups is established. The rock matrix rock deformation analysis and deformation analysis methods are discussed respectively, and the rock deformation analysis model is obtained.

(3) The method of determining the model parameters of the line is used to establish a simulation method for the dynamic deformation process of the rock. It can not only reflect the stress state, but also reflect the influence of strain rate on the rock deformation process. Finally, by comparing and analyzing the theoretical and experimental curves of similar models, the rationality and superiority of the proposed model and method are proved.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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