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# Digital Simulation Study on Stress field Distribution during Mining Face Excavation

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**ABSTRACT:** The RFPA2D software is used to simulate the redistribution of ground stress caused by mining face distribution and excavation, and simulate and analyze the fracture process of overlying strata and the distribution of stress field with the advance of mining face. This "RFPA method" is a new numerical simulation method based on the basic theory of finite element, which is put forward by Tang Chun'an and others in response to the problem that "the internal micro-fracture of rock will continue to occur during the loading process, and the rock will produce nonlinear deformation, and the continuous development of this micro-fracture will lead to the final macro-fracture". This method fully takes into account the characteristics of nonlinearity, heterogeneity and anisotropy in the rock fracture process, That is, rock fracture process analysis method. Through numerical simulation, the fracture, movement and stress distribution of overlying strata with unsynchronized number in the excavation simulation process are obtained. Finally, the fracture and instability of the strata are judged according to the established damage model. This numerical simulation method intuitively observed the movement and fracture law of the overlying strata in the coal mining face, and preliminarily established the relationship between the physical and mechanical parameters of rock and the actual engineering. This mathematical model well applied the rock mechanics theory to the coal mining practice, laying a foundation for future work.

**KEYWORDS:**RFPA2D; Stress distribution; Digital simulation; Rock damage.

## I. INTRODUCTION

Natural rock mass is a discontinuous, heterogeneous, inelastic and anisotropic medium. It has timeliness, memory and dependence on the environment. The nonlinear deformation of rock is due to the continuous occurrence of micro-fracture in the rock during the loading process, and the continuous development of this micro-fracture will lead to the final macro-fracture.

In view of these problems, Tang Chun'an and others proposed a new numerical simulation method "RFPA method" based on the basic theory of finite element, which fully considers the characteristics of nonlinearity, inhomogeneity and anisotropy in the process of rock fracture, that is, the analysis method of rock fracture process. Its main points are as follows:

(1) The heterogeneity parameter of rock material is introduced into the calculation unit, and the macro failure is the accumulation process of unit failure.

(2) It is considered that the properties of the element are linear elastic-brittle or brittle-plastic, and the elastic modulus and strength of the element and other parameters obey a certain distribution, such as normal distribution, Weber distribution, uniform distribution, etc.

(3) It is considered that when the element stress reaches the failure criterion, the failure occurs, and the stiffness of the failure element is degraded, so the physical non-continuous medium problem can be treated by the continuum mechanics method.

(4) It is considered that the damage amount and acoustic emission of rock are proportional to the number of failure elements.

## II. STEPS AND METHODS OF DIGITAL SIMULATION

### (1) Construction model

#### ① Establish engineering documents

Start RFPA2D -- Basic in the program group or the start menu of Windows 2010. After the system working platform appears, select the new command from the file menu or toolbar to open the naming dialog box. In the file name column, set "RFPA2D -- Basic" as the name of the problem to be simulated.

#### ② Meshing

After confirming, the system will enter the working platform status. A dialog box will pop up according to the grid division command, and the grid cells will be divided according to a certain proportion.

#### ③ Insert Model Structure

The model after dividing the cell grid is as follows:



Figure 1 Cell grid model

#### ④ Boundary conditions and loading conditions

The assignment of boundary conditions and loading conditions (control conditions) is to set the boundary conditions and loading conditions and system customization for the above designed model, and assign values through the shortcut keys or the boundary and control buttons on the toolbar. These assignments are to select appropriate conditions according to specific engineering problems. Boundary condition: the loading direction is Y direction, the constraint condition is plane strain, the loading displacement is 0.003mm, and the control information: the total number of loading steps is 50, the gravity direction is None, and the intermediate step is not displayed.

#### (2) Calculation

It is better to save the constructed model before the calculation to prevent the loss of document data in case of computer system failure, such as power failure, program error, virus attack, etc. RFPA2D-Basic - The operation mode of the software system is single-step operation.

#### (3) Result analysis

##### ① Form of destruction

##### ② Damage evolution

It is well known that in the study of damage mechanics, in order to describe the law of damage evolution in materials, an internal parameter variable, namely damage variable, is introduced, which is defined as:

$$D = 1 - \frac{\tilde{A}}{A}$$

In the formula, D is the damage variable, A is the cross-sectional area of the material in the undamaged state, and is the effective cross-sectional area of the material in the damaged state. When D=0, the material is not damaged; when D=1, the material is completely damaged. Generally, when the material is completely destroyed, D<1, the damage variable is defined as the critical damage variable DC.

Rock is a typical damage material, and its damage process is the comprehensive performance of internal micro-fracture. Since the size of elements in the RFPA2D model is the same, the damage variable can generally be defined as:



$$D = n / N$$

Where: n is the number of damaged elements; N is the total number of units in the model..

### III. DIGITAL ANALOG CONTENT

The model is divided into five layers of rock strata with different lithology (including coal seams). The physical and mechanical parameters are shown in Table 1 below. There are two joint planes, and the joints are located between two adjacent rock strata above the coal seams, as shown in Table 2 below.

Table 1 Rock stratum parameters

position	evenness	Elastic modulus	compressive strength	dead weight	MS-T	MS-C	Compression ratio
Joint	50	1000	10	2.0	1.0	20	50

Model size 50m × 100m, gridded into 100 × 200 units. The horizontal direction is constrained by displacement, and the vertical direction is controlled by gravity. The movement of the mining face is simulated through excavation. A total of 5 steps are excavated, 25 units are excavated to the right in each step, and the excavation height is 2.5m.

Set and calculate the above model parameters, boundary conditions and control conditions in RFPA2D -- Basic software.

Table 2 Joint parameters

sequenc e	lithology	Thicknes s (m)	Elastic modulus (MPa)	Compressi ve strength (MPa)	Dead weight (N/m <sup>3</sup> )	Friction angle (degrees)	Poisson' s ratio
Top plate 3	Sandston e	30	8000	80	2.6	30	0.25
Top plate 2	Sandston e	7.5	4500	45	2.5	35	0.30
Top plate 1	Sandshal e	5	2500	25	2.5	37	0.30
Coal seams	Sandshal e	2.5	1000	25	1.6	38	0.35
floor	Sandston e	5	10000	100	2.6	30	0.25
			0		5		



#### IV. SIMULATED EXPERIMENTAL DATA

The following is the overlying strata fracture, movement and stress distribution diagram calculated by the software program from the first step to the fifth step of excavation.

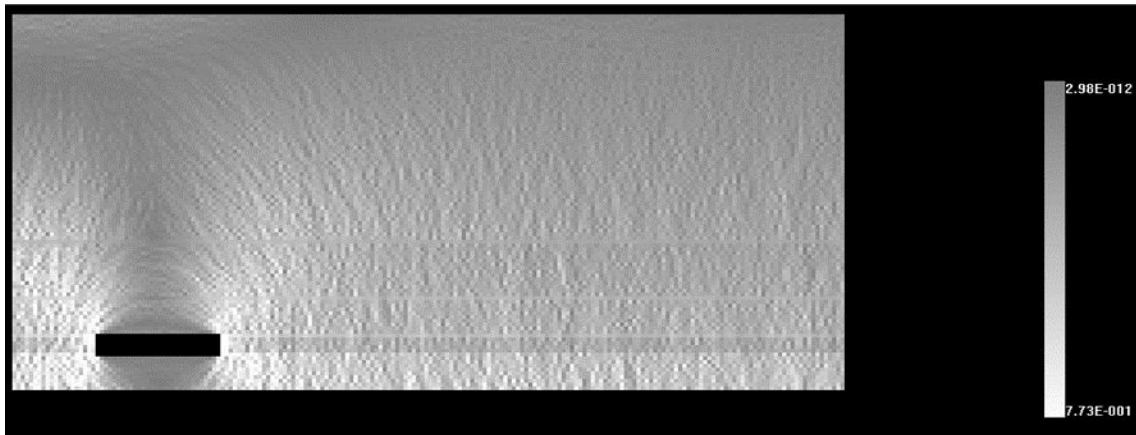


Fig. 2. Rock movement and stress distribution in the first step of excavation

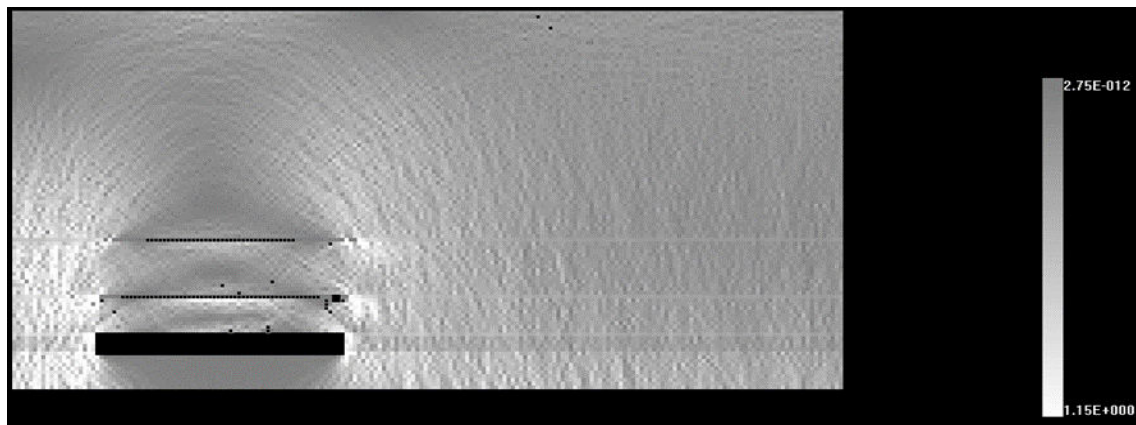


Fig. 3 Stratum movement and stress distribution in the second step of excavation

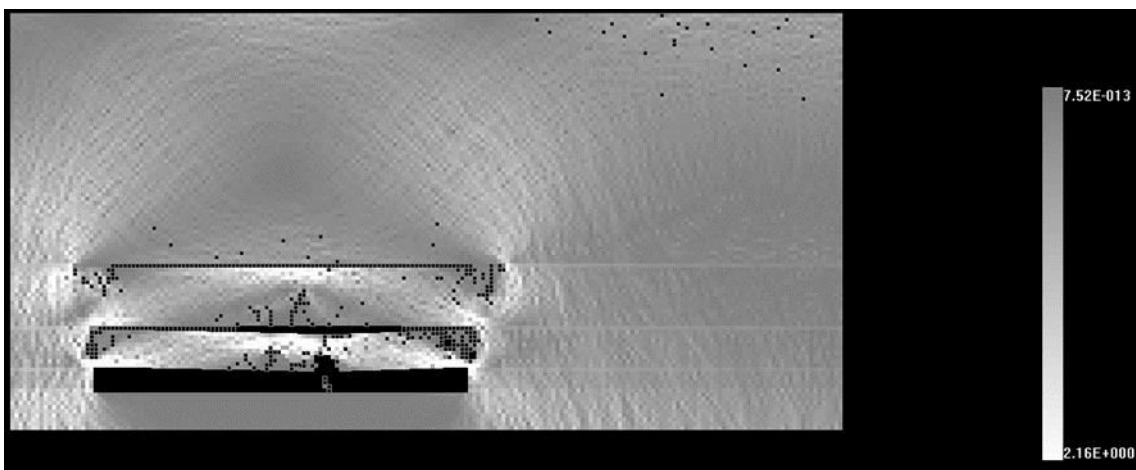


Fig. 4 Stratum movement and stress distribution of the third step excavation

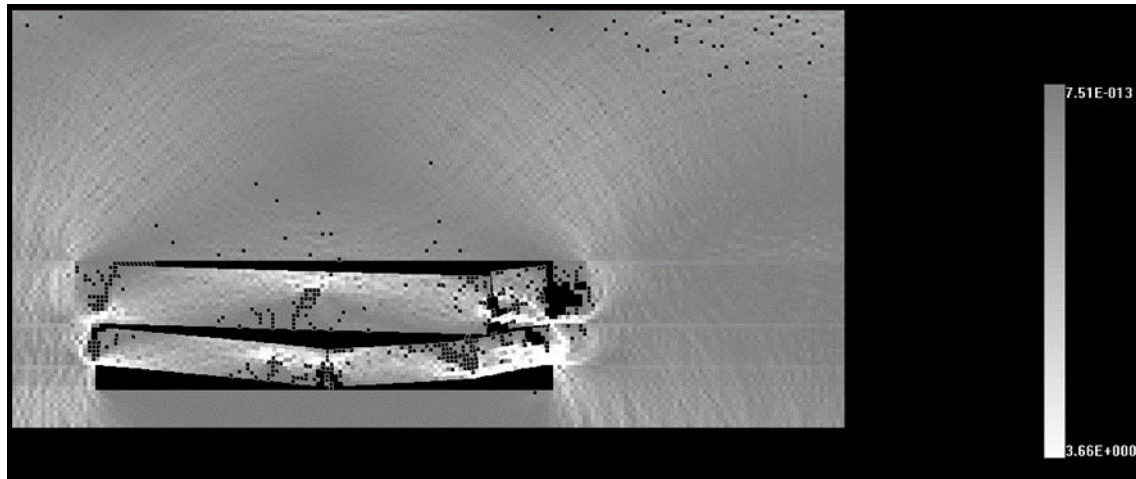


Fig. 5 Stratum movement and stress distribution of the fourth step excavation  
Stratum movement and stress distribution of the fourth step excavation

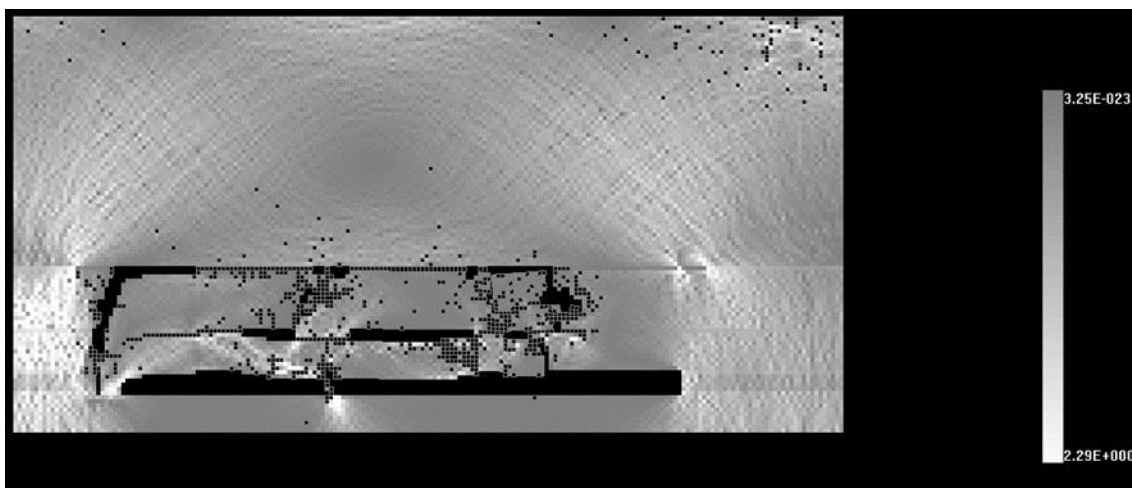


Fig. 6 Stratum movement and stress distribution of the fifth step excavation

## V. DATA PROCESSING AND RESULT ANALYSIS

It can be seen from the above figures that the joint surface is most seriously affected by mining, and the damage is generated here and further developed. When the strength of the rock stratum reaches the limit, it will break, which is manifested in the development of cracks and pores at the macro level until they are connected. In this process, it also causes the redistribution of geostress.

Damage variable:

$$D = n / N$$

Where, n is the number of damaged elements; N is the total number of units in the model.

Measured in the experiment, n=45, N=96

It can be seen from  $D=0.46875 < 1$  that the rock specimen material is damaged.

Displacement analysis in Y direction:

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Displacement analysis in Y direction:

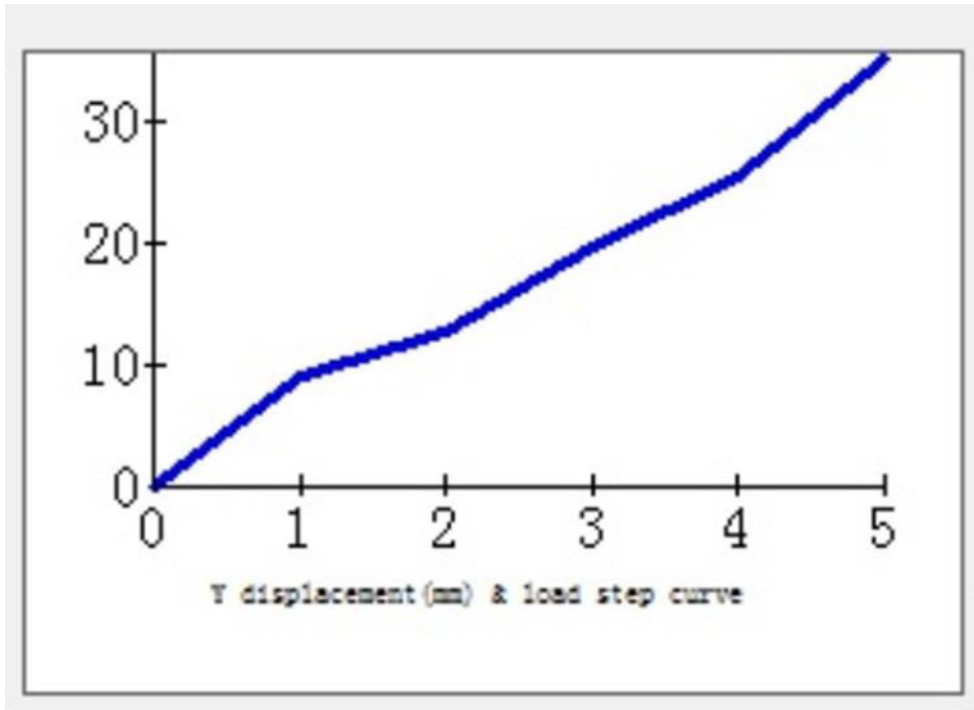


Fig 7 Displacement in Y direction

Acoustic emission analysis:

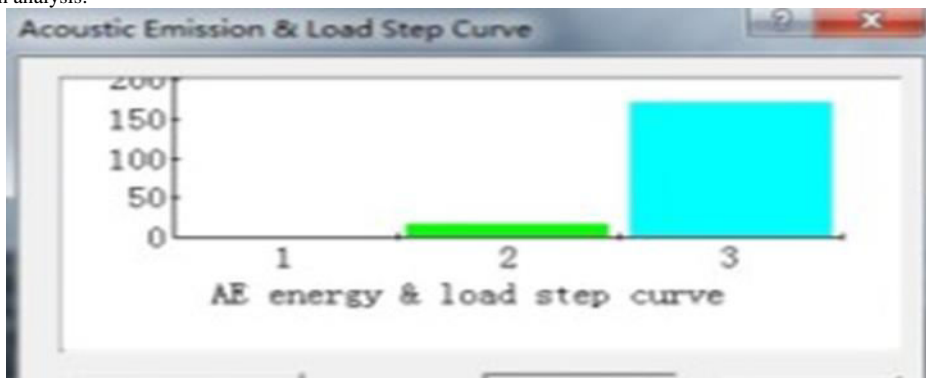


Fig 8 Acoustic emission energy and load step curve

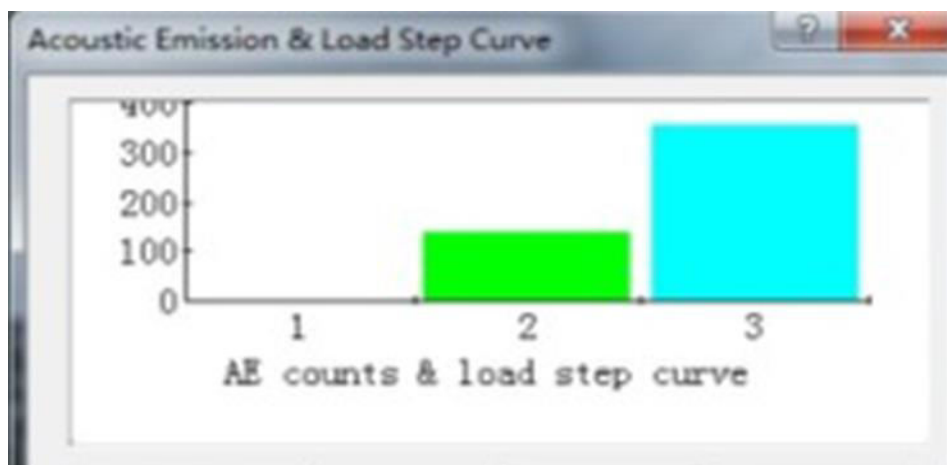


Fig 9 Acoustic emission event and load step curve

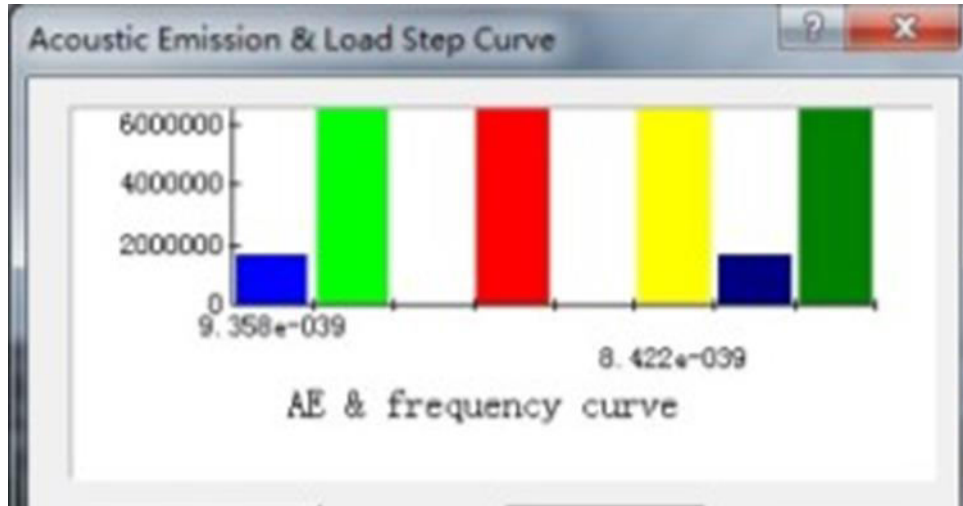


Fig 10 Acoustic emission signal frequency curve

Load case analysis:

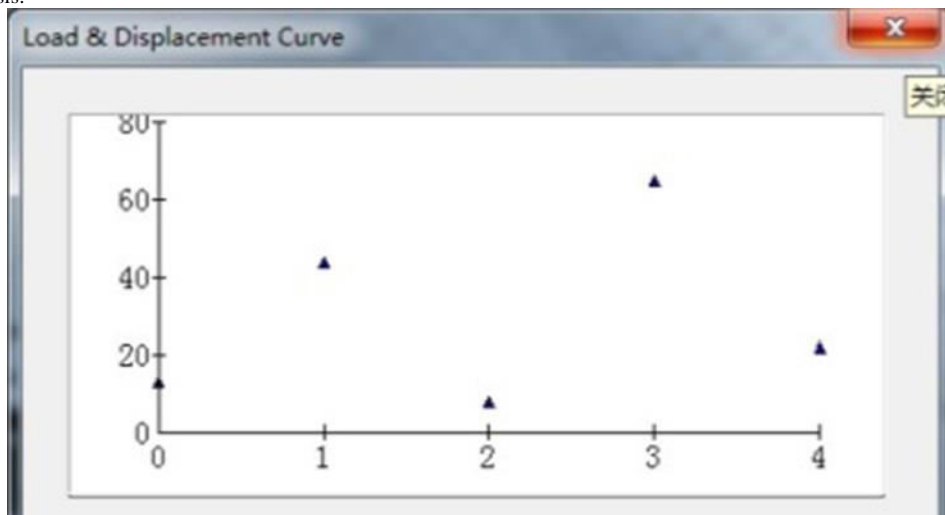


Fig 11 Load and displacement curve

## VI. CONCLUSION

At present, the research on rock fracture and instability process mainly depends on field observation and experimental physical experiments, but numerical simulation as an auxiliary means is also widely used. Through the teacher's explanation and practical guidance, I have gained a lot after completing the teaching session: I have mastered the use of RFPA2D-Basic software, observed the movement and fracture of the overlying strata on the coal mining face intuitively, and preliminarily established the relationship between rock physical and mechanical parameters and actual engineering, laying a certain foundation for future work

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