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Risk Assessment of Cross-fault Water Pipeline Based on Finite Element Simulation：A Case Study of Ahong Main Canal

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Objectives

For large pipeline projects involving multiple seismic zones,it is very important to accurately assess the pipeline safety of typical sites. In order to ensure the safety of pipelines in the action of active faults and improve the earthquake-resistant and disaster-mitigation capabilities of pipeline, this paper takes the fifth section of the AHong main canal pipeline in Yuxi area of the second stage diversion project in central Yunnan as an example to study the failure risk of pipelines under the action of active faults. The effects of mechanical parameters, displacement load and uncertainty of soil parameters on pipeline response are considered. The effects of earthquake magnitude, pipe wall thickness and filling depth on the failure probability of selected pipelines are also discussed.

Methods

The built-in pipe-soil interaction（PSI）element of ABAQUS software is used to estab-ish a finite element model controlled by seismic displacement，taking into account the uncertainty of seismic displacement load，pipe strength and undrained shear strength of soil，and the maximum axial tensile strain and compressive strain are used as the response values to obtain the distribution of pipeline response. Based on the Monte Carlo simulation method，the failure probability of the pipeline under a given working condition is calculated.

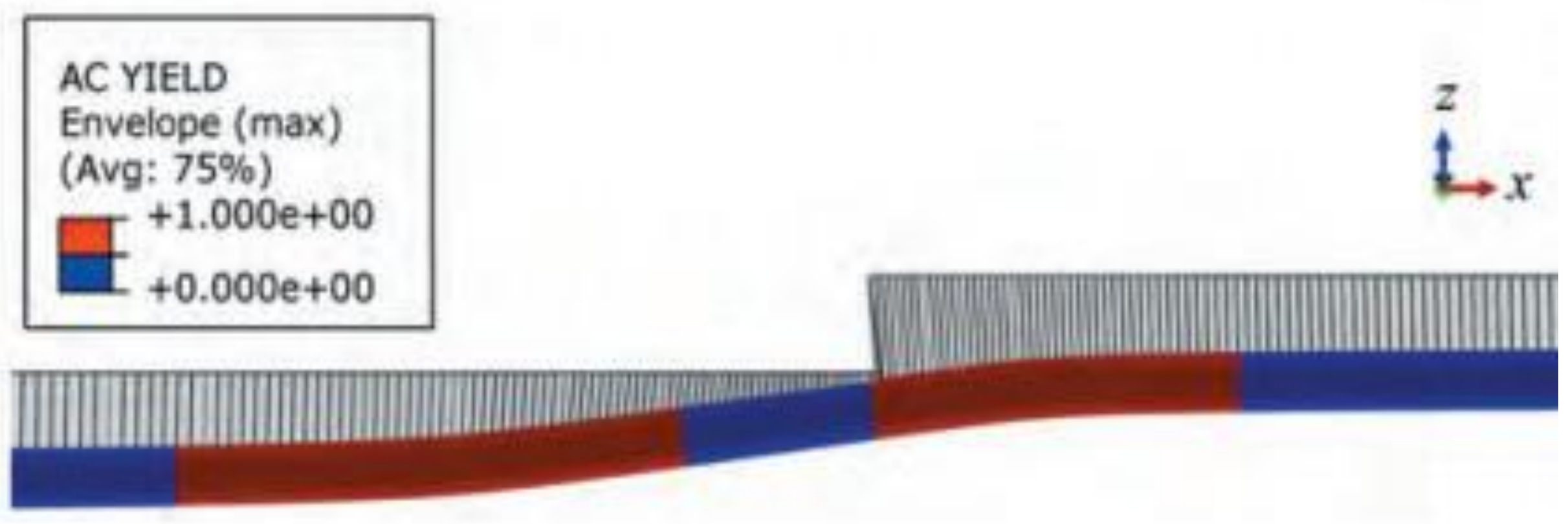

Fig.2 Partition map of pipeline elastoplastic（M = 6.3

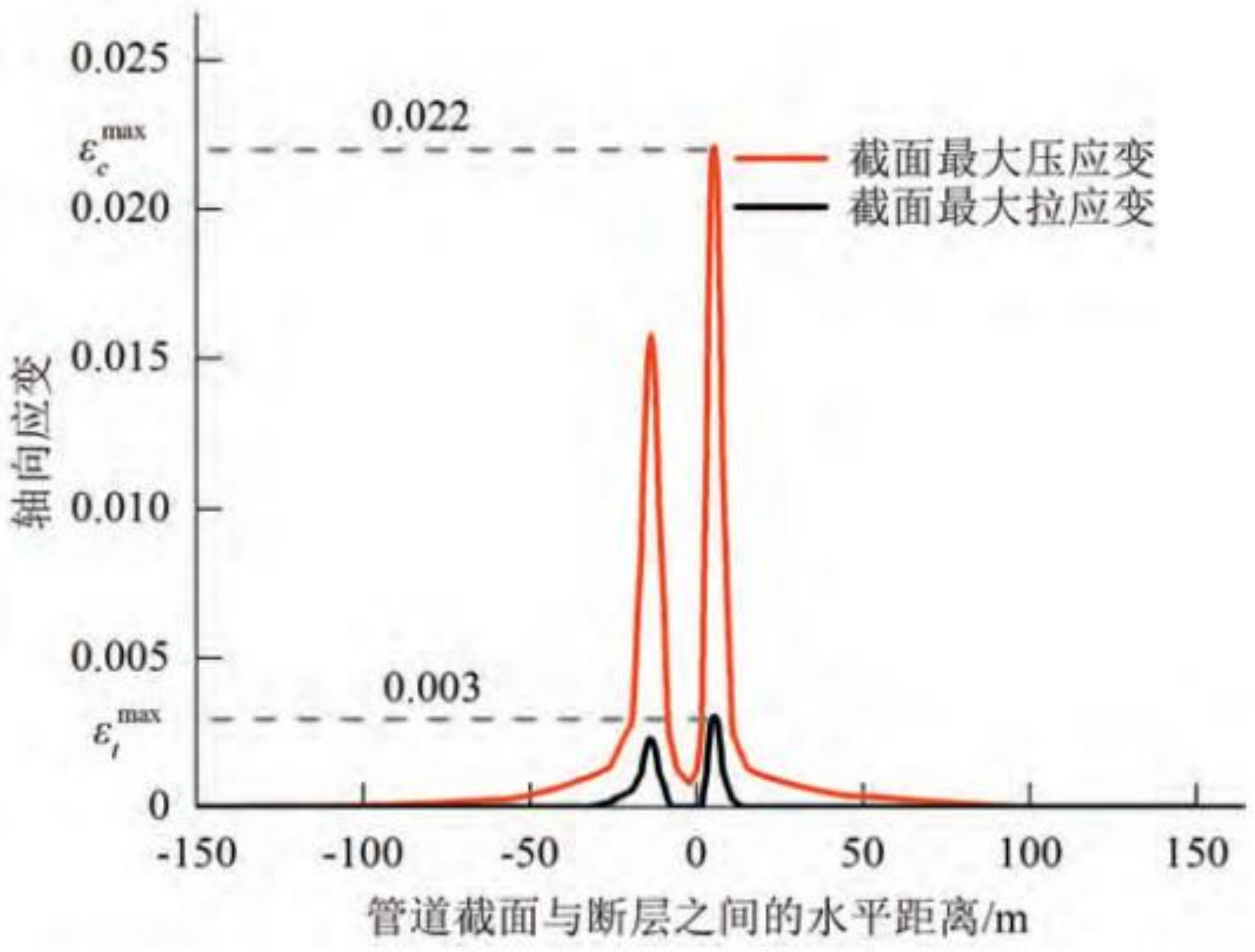

Fig.3 Axial strain envelope of pipeline

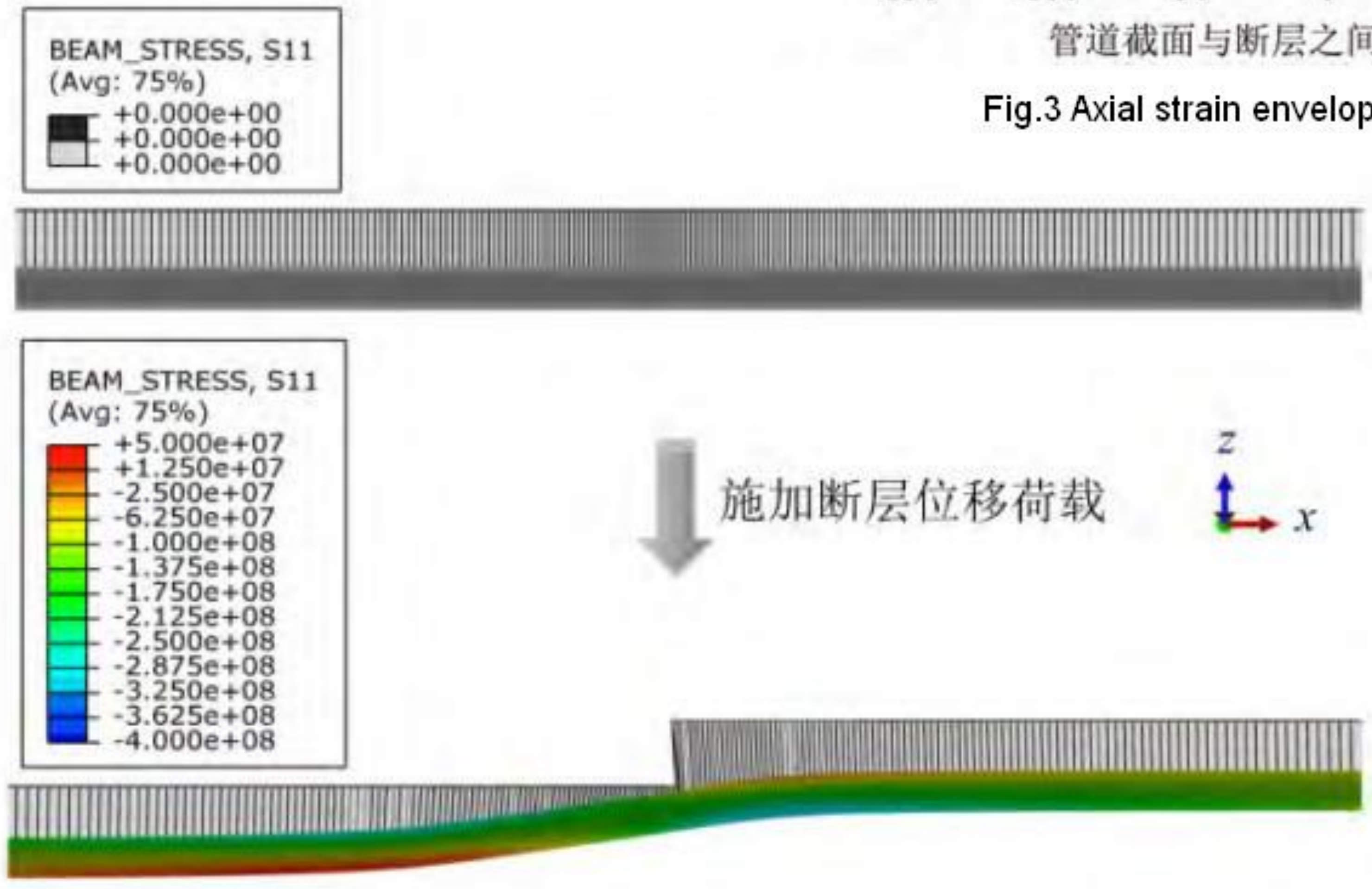

Fig.1 Axial stress cloud map of pipeline（M = 6.3）

Results

1. Analysis of certainty Results

The displacement of the pipeline occurs in three directions along with the soil mass, but mainly in the vertical direction. When the pipeline moves upward on the right side, the upper part of the pipeline is strained and the lower side is pressured. Due to the displacement component of the reverse fault in the horizontal direction, the pipeline may be subjected to severe local pressure. As shown in Fig.1, "S" deformation occurred in the pipeline after fault dislocation occurred, and axial compression strain occurred in most areas. The red area in Fig.2 indicates that the pipeline has undergone plastic deformation. It can be seen that most areas of the pipeline near the fault have entered the plastic stage. Fig.3 shows the envelope diagram of axial strain of the pipeline. As shown in the figure, the maximum tensile strain ε_t^{max} of the pipeline is 0.3%, which is less than $[\varepsilon_t]_F$, and the maximum compressive strain ε_c^{max} of the pipeline is 2.2%, which is greater than $[\varepsilon_t]_F$, resulting in the pipeline compression failure.

2. Analysis of Uncertainty Results

Fig.4 shows the distribution diagram of the maximum tensile strain of the pipeline based on 1,000 random samples, where the horizontal axis represents the maximum tensile strain value of the pipeline, the left vertical axis represents the sample frequency corresponding to each square interval, and the right vertical axis represents the cumulative frequency of the sample. According to the strain failure criterion, a total of 744 failure samples can be obtained when the earthquake magnitude M is 6.3. In Fig.5, about 90% of the maximum axial tensile strain of random samples falls between 0 and $[\varepsilon_t]_F$ ， and 26.6% of the maximum axial compressive strain of random samples falls between 0 and $[\varepsilon_t]_F$ .the failure samples fail due to local compression, and 10% of the samples have both tensile and compression failures. Furthermore, in this example, the response of the mean of the random variable is approximately the median of the response in the stochastic simulation. When a magnitude 6.3 earthquake occurs, the failure probability of the pipeline is 74.4%, which is mainly caused by large compression strain.

Conclusions

1. 2D model can be used for stochastic simulation to improve computational efficiency.

2. The sensitivity analysis results show that earthquake magnitude and pipe wall thickness have a greater influence on the failure probability of the pipeline, while the filling depth has a lesser influence on the failure probability of the pipeline.

3. In this calculation example, it is possible to consider using pipes with higher strength or reducing materialsThe Angle between the small fault and the pipeline can reduce the axial displacement load and improve the safety of the project.

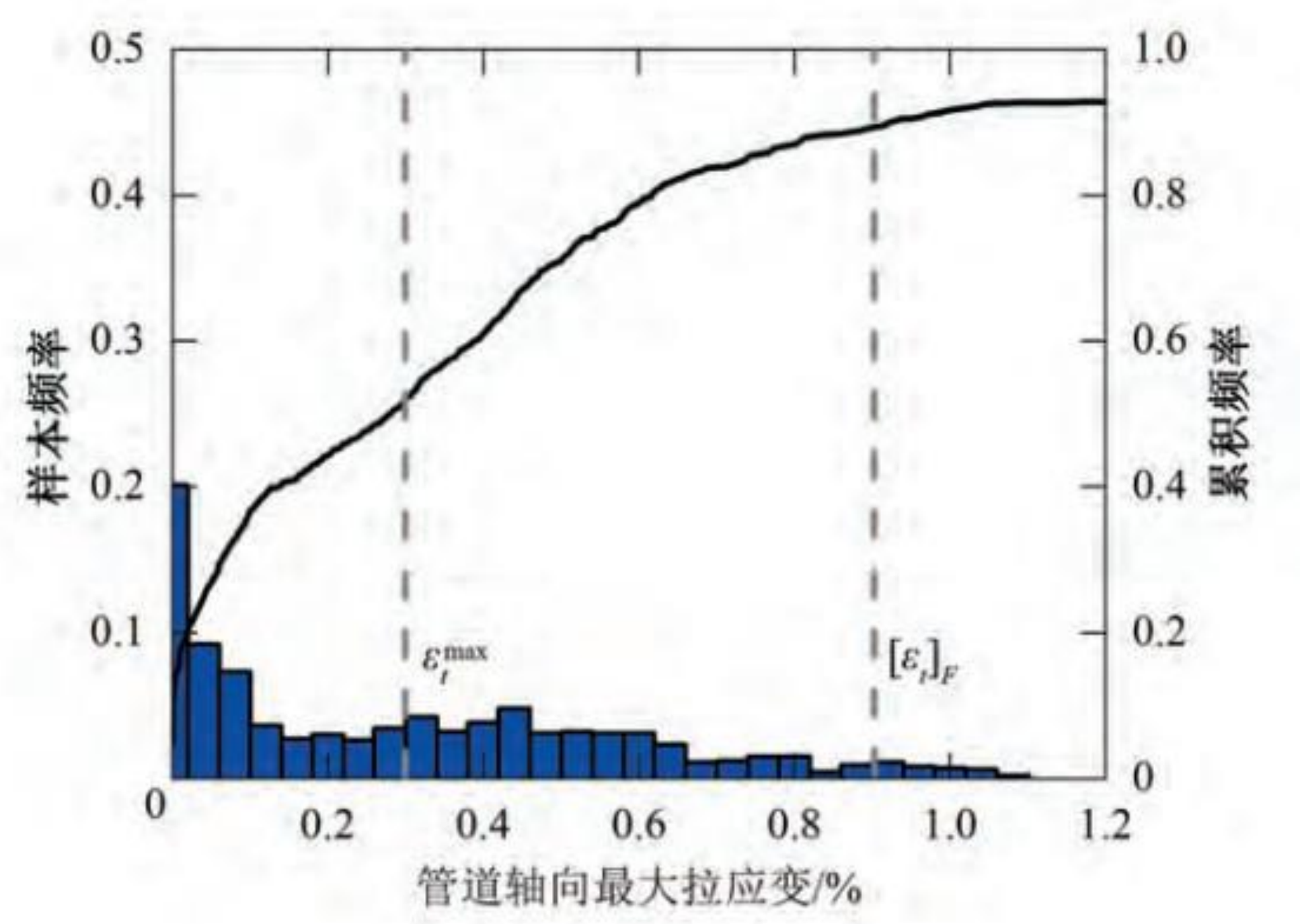

Fig. 4 Results of stochastic simulation M = 6.3（Maximum axial tensile strain）

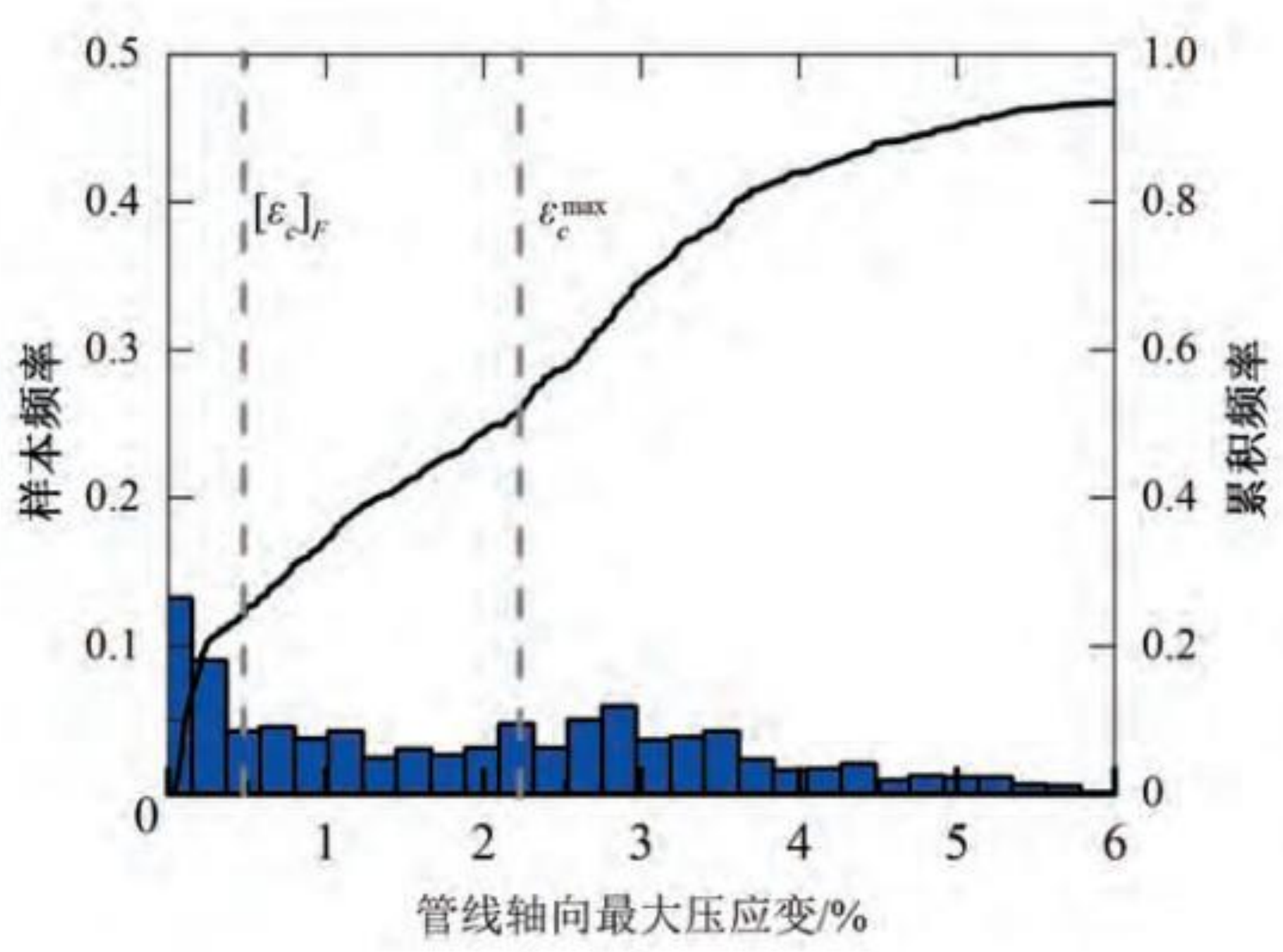

Fig. 5 Results of stochastic simulation M = 6.3（Maximum axial compressive strain）

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