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Analysis of Crack Propagation based on XFEM

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Abstract: The destruction of the bridge structures, etc, most of the time, began with cracks. Application of extended basic theory of finite element method (XFEM) and use of common software abaqus to fracture analysis, a middle beam cracks were concluded in the external loads, and got the stress changes of the artifacts and crack propagation.

Keywords: XFEM; Crack Propagation; Fracture Mechanics

1. Introduction

Engineering practice shows that the crash of structure closely linked with the crack development, the bearing capacity are decreased by the existence of crack, and it influenced the normal use of structure. So, it is important to study the crack and the development theory, so that we can make sure the safety and durability of engineering structure. Lately, the research methods of fracture and damage are FDM, FEM, BEM, XFEM, etc.

The XFEM method was developed by Prof. Belytschko, it was widely used and improved by engineers, and widely used in various areas. The first edition of XFEM could only use in some simple plane problem, and must be regular shape, most important, it must be single crack problem. Few years later, Sethian put the level set method into the description of crack, and combined with the finite method, so that we could analysis more difficult crack problems; Stolarska did the same thing too, and pushed it to track the development of cracks. Chopp used the FMM and the XFEM simulated multiple cracks, it was proved success.

2. Introduction to the theory of fracture mechanics

Fracture mechanics was a discipline that developed in lately 20 years, it is based on the linear elastic mechanics and Elastic-plastic mechanics, it can analysis the appearance and development of cracks under the load both inside and outside, and find out the change rules. Study the resistance performance of the material to the crack, so that we can evaluate the safety and durability of structure. In this paper, we analysis the crack model by using the finite element software ABAQUS.

In fracture mechanics, the same material under different load have varies forms. There are three crack methods in engineer, they are: opening mode (mode I); sliding mode (mode II); tearing mode (mode III). The first mode is the most common, basic and dangerous .

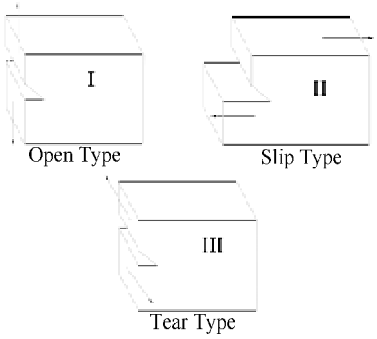

Figure 1. Basic modes of crack fracture

Based on the linear elastic mechanics theory, in order to confirm if the crack will develop, we can estimate it by stress intensity factor, use the mode I as example, the stress intensity factor expression as follow:

$$K_I = Ys\sqrt{pa} \quad (1)$$

It is inversely proportional to the crack size "a" and the stress "s" the structure bear. The cracked structure must satisfied the condition:

$$K_I < K_{IC} \quad (2)$$

So that the structure can be safely. In the equation, K_I stand for stress intensity factor; K_{IC} stand for the fracture toughness of material, it can be acquired in fracture test.

3. The finite element model

The basic information of the model is that the length, width and height are l=3m, h=6m, t=1m, the length of initial crack is 1.5m, the elasticity modulus E=210GPa, and the Poisson's ratio is 0.3. According to the material property, the maximum principal stress is the criterion of injure, and the value is 84.4Mpa. The development of the crack is based on energy, linear softening and mixed

model, the value of some parameters is G1C=G2C=G3C=42200N/m, $a=1$.

According to the mentioned working condition and the component geometry information, we established an analysis model based on the finite common software of ABAQUS. Mesh structure adopted by the rules of the Hex hexahedral grid unit, there are 7558 elements and 18071 nodes, the element type is C3D8R (Hexahedral integral unit), the graphic boundary and load is shown as Figure 2, the mesh result as shown in the Figure 3. The final structure model diagram as shown in Figure 4.

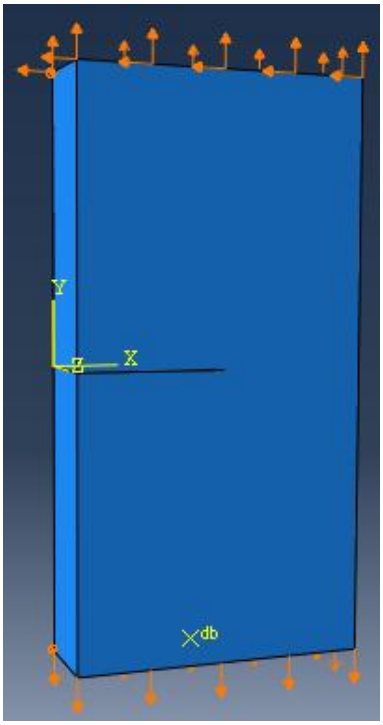

Figure 2. Graphic boundary and load

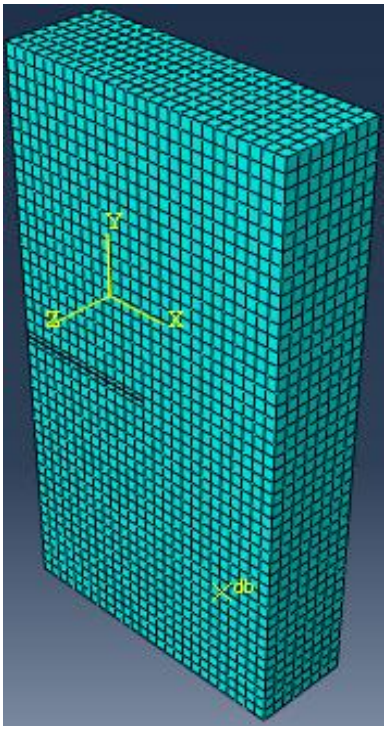

Figure 3. The results on gridFig

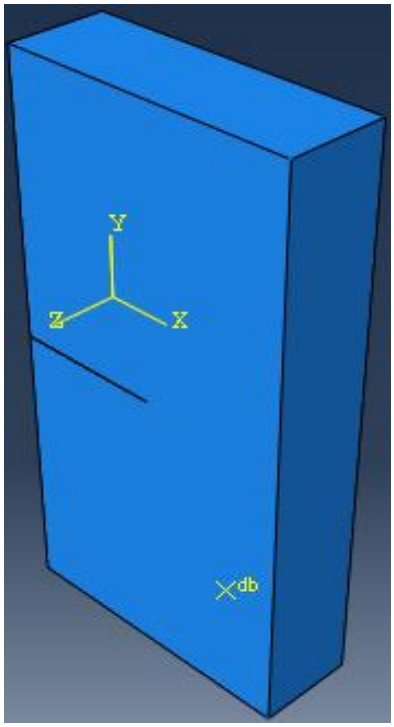

Figure 4. Structural model figure

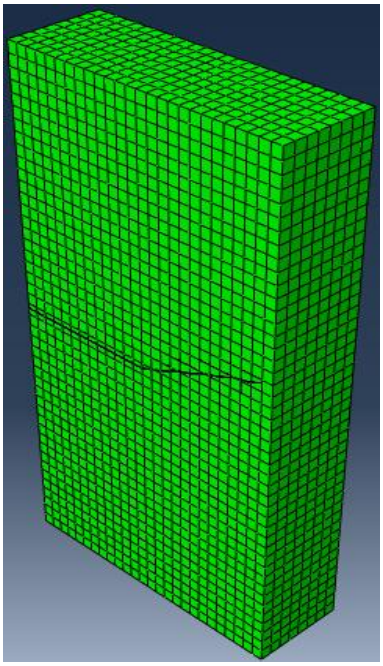

Figure 5. Structure diagram of crack in the end

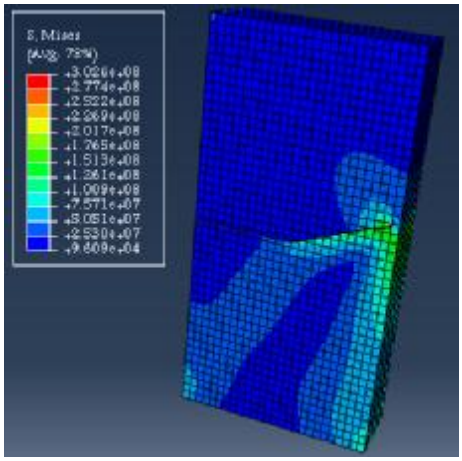

Figure 6. The equivalent stress nephogram of structure

4. Results analysis

By the analysis of result, the development of the crack path does not comply with the laws of a particular, but closely linked with the stress of structure and towards the maximum stress position. It is related to the stress intensity factor, once the stress intensity factor bigger than fracture toughness of material, the crack will begin to expand. The path of the crack development is shown is Figure 5. Throughout the process, stress changes mainly around the crack, Figure 6 represents the structure of the equivalent stress diagram.

In the process of crack propagation studies, the most important research object is the crack tips. Pick one of the tips in the crack path as the research object, Figure 7 showed the stress change to that point. By the analysis results can be seen that at the beginning of the load, the stress of the crack tip is increasing by linear relationship, it will drop down sharply once reached the peak, and then steps down trend.

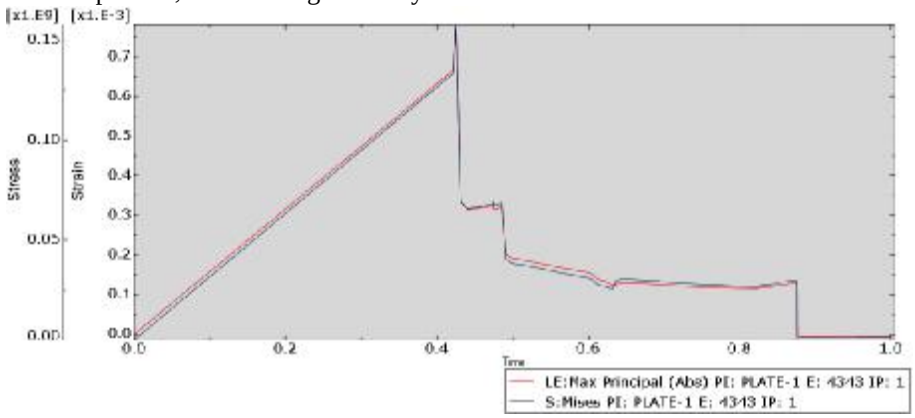

Figure 7. The stress at the crack tip

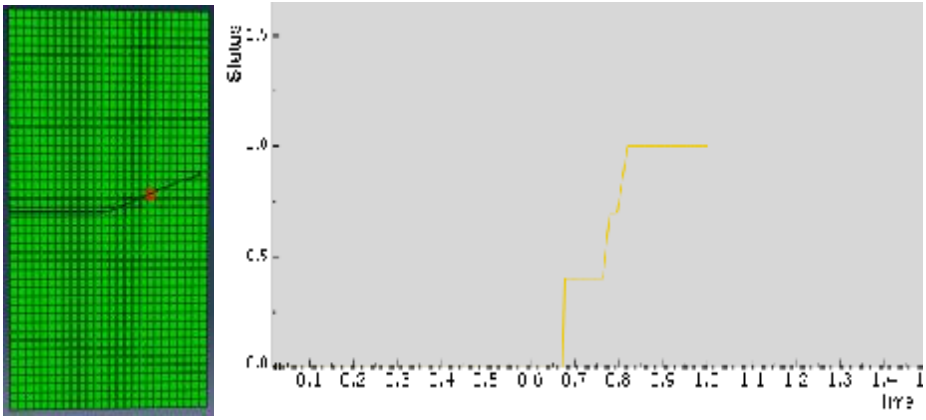

Figure 8. The curves of strain energy at some point

Figure 8 shown the change of the strain energy in the process of crack propagation path within a certain unit structure, the results of the analysis found that there is no strain energy before the crack reached, which means there is no strain. But the strain energy will increase sharply once the crack arrive, it means that the strain happened all of a sudden, and it isn't increased by linear relationship. After that, it will increase after hold for 0.1 second, finally reached the most strain and stop location. Analysis of whole crack propagation process, we find that the stress in the crack growth and decline in the trend. It is not hard to understand, the sectional area of bearing load is smaller as the growth of the crack, so that the structure bearing capacity reduced gradually.

5. Conclusion

As the latest numerical analysis method, XFEM is based on the theory of decomposition, it puts the discontinuous displacement mode into the traditional finite element analysis, it makes the discontinuous displacement field description independent of meshing, so that the discontinuous interface can be through the grid during the XFEM analysis process. What is more important, we don't need to set the cracking path adjustment and grid anymore when simulating crack propagation process, we can in-

crease the discontinuous displacement model to represent the processes of the discontinuous interface. In this article the research content, we can significantly improve the efficiency of crack growth analysis by using the XFEM to analysis the crack development of structure. And build a foundation for the further analysis of crack propagation of structural failure mechanism, and we can create more value for our society by improve the service life of structure.

References

[1] Li Shu-cai.Mechanical Character of Anchoring Discontinuous Joint Rock Mass and its Application [J], Journal of China Coal Society, 1997, 22(5).

[2] LI Shu-chen, LI Shu-cai.Analysis of fluid-solid coupling for slope stability of cofferdam in water [J], Rock and Soil Mechanics, 2004,25 (1):82-86.

[3] ZHU Bai-fang, Principle and Application of Finite Element [M], Beijing, WaterResourcesandElectricPowerPress, 2009

[4] CEHNG Yu-min, HUANG Ai-xiang. Boundary Element Analysis Package BESMAP and its Engineering Application [J], Journal of TONGJI university, 1996, 24(6).

[5] CEHNG Yu-min. The Method of Weighted Residuals Analysis Package MWRAP and its Application in Engineering [J], 2000. 21(4).

[6] ZHU He-hua, CHEN Qing-jun, YANG Lin-de. The Boundary Element Method and its Application in the Geotechnical Engineering [M],Shanghai, Tongji University Press,1997

[7] Christophe Daux, Mose, Dolbow, Sukumar, Belytschko. Arbitrary Branched and Intersecting Cracks with the Extended Finite Element Method[J]. International Journal for Numerical Methods in Engineering , 2000,48:1741-1760

[8] Belytschko T, Black T. Elastic Crack Growth in Finite Elements with Minimal Remeshing[J]. International Journal for Numerical Method in Engineering, 1999, 45:601-620

[9] Sethian. Level Set Methods and Fast Marching Methods: Evolving Interfaces in Computational Geometry, Fluid Mechanics. Computer Vision, and Materials Science [M]. UK: Cambridge University Press, 1999

[10] Stolarska M, Chopp, Moes eta1. Modelling Crack Growth by Level Sets in the Extended Finite Element Method[J]. International Journal for Numerical Methods in Engineering, 2001, 5l (8): 943-960

[11] Chopp DL, Sukumar N. Fatigue Crack Propagation of Multiple Coplanar Cracks with the Coupled Extended Finite Element and Fast Marching Method[J]. International Journal of Engineering Science, 2003, 41(8):845-869

[12] CHENG Jin, ZHAO Shu-shan.Fracture Mechanics [M], Beijing: sciencepress, 2006

[13] ZHANG Heng. Fracture and Damage Mechanics [M], Beijing, Beijing university of aeronautics and astronautics press,2006

[14] YU Rao-zhong. Rock and Concrete Fracture Mechanics [M], Changsha, Zhongnan industry press,1991

[15] TU Shan-dong. The Principle of High Temperature Structural Integrity [M], Beijing, sciencepress,2003

[16] ZHUANG Zhuo. Finite Element Analysis and ApplicationBased on ABAQUS [M], Beijing,TsinghuaUniversityPress,2009