Numerical calculation of material configurational force based on ABAQUS secondary development and its applications

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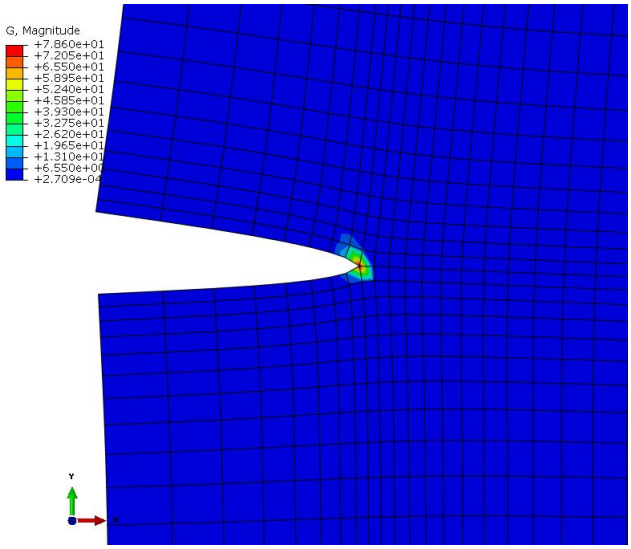
Abstract

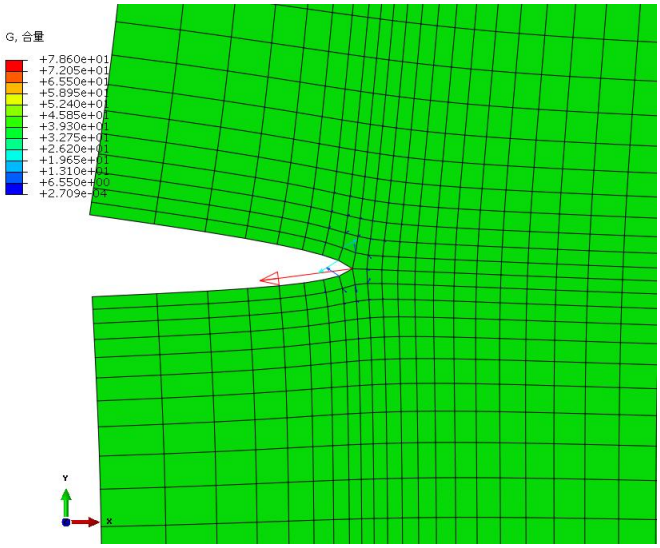
The configurational force has a unique advantage in reflecting the change of defect configuration and damage evolution of the material. The mechanics of material configuration is mainly concerned with the change of the free energy of the system when the defects (inclusions, voids, dislocations, cracks, etc.) are changed, which can be applied to predict the critical failure load and evaluate the structural integrity. By the gradient, divergence and rotation operation of Lagrange function, three classes of materials configuration expressions of the stress tensor b_{ij}, M_i, L_{ij} and the corresponding integral J_k- integral, M- integral, L- integral can be obtained , which can be interpreted as the potential energy change caused by translation, self-similar expansion, and rotation of the material element[1]-[4]. However, there is a lack of general calculation program for the configurational force up to now. In this paper, based on the secondary development of ABAQUS post-processing, the program of Python is used to realize the numerical calculation of three classes of material configurational force, and to further realize the applications in the evaluation of material damage.

Firstly, the equilibrium equation between the configurational stress and the configurational force is obtained. A weak formulation is presented to compute discrete configurational forces, and the definition of the nodal configurational force is given [5]. By considering the contribution of each surrounding finite elements to the nodal configurational force, the method of calculating the nodal configurational force in the finite element is obtained. Next, in order to realize the application of configurational force theory in finite element software ABAQUS, the program code of Python is applied to the secondary development of ABAQUS post-processing. Through the program, the calculation of the node configurational forces are realized. And the accuracy of the program is verified by the numerical simulation of crack program in linear elastic material, as shown in Fig.1. Finally, the computing method of the configurational force is applied to evaluate the material integrity of other defects, such as inclusion and interface. The open program code developed in this study will be beneficial in analyzing the damage and crack problems by the material configurational forces.

Keywords: Configurational force; Damage; Finite element; Secondary development



(a) Contour of configurational force near the crack tip



(b) Diagram of Configurational force vector near the crack tip

Figure 1. Configurational force near the crack tip

($G^2=G_x^2+G_y^2$, where $\boldsymbol{G_x}$ denote the configurational force component along x-direction., $\boldsymbol{G_y}$ denote the configurational force component along y-direction)

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