SHARP V-NOTCH TIP FIELDS CONSIDERING OUT-OF-PLANE EFFECT UNDER CREEPING CONDITION

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Abstract
Notches in creeping solids at high temperatures have drawn considerable attention due to their importance in structural integrity assessment. Understanding the three-dimensional (3D) effect on the notch tip field is important for the fracture mechanics analysis of engineering materials and structures. This paper presents an rigorous asymptotic solution for 3D sharp V-notched structures subjected to mode I creep loading condition.

1. Introduction

Evaluation of the three-dimensional (3D) notch tip field is a significant topic for various engineering materials which has been discussed widely in the field of fracture mechanics. Recently, with the development of industrial technologies, structural integrity assessment at elevated temperature has become more and more important, accompanying with the rising interests in the notch tip field in creeping solids. Reliable structural design requires highly accurate estimation of the notch tip field for creeping or viscoplastic solids. To this end, the rigorous analysis of the 3D effect on the notch tip field under creep condition is a prerequisite since previous work indicated that there should be an obvious discrepancy between 3D and 2D creeping notch tip field. We would like to address this issue in this work with a particular focus on the 3D effect works on the creeping V-notch tip field.

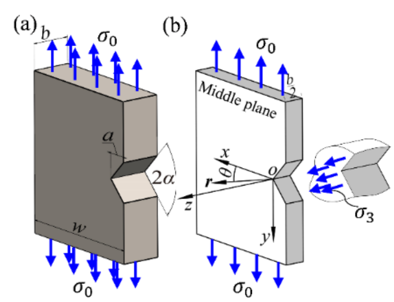

Fig. 1 (a) Specimen geometry and loading (b) Coordinate systems at middle plane of the 3D notch

2. Results

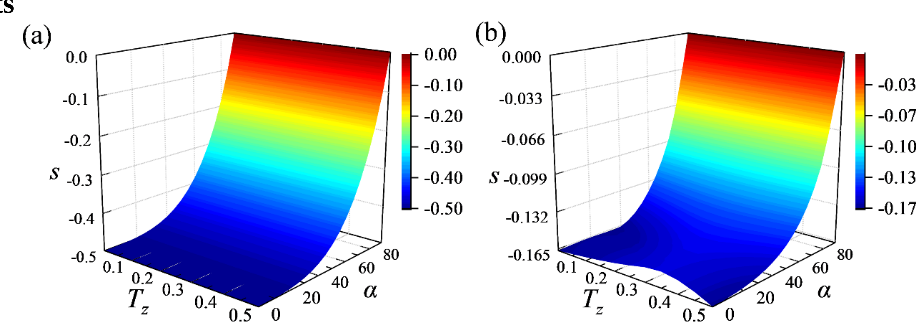

Fig. 2 Variations of stress exponent with different out-of-plane constraint factor and notch

The asymptotic solution, including the singularities and stress field distribution functions, is obtained by introducing the out-of-plane constraint factor. It is found that the singular behavior is related to the notch angle, material creeping exponents, and the out-of-plane constraint factor. Specifically, singularity changes sharply near the free surface. Asymptotic solution is presented to describe the mode I stress field around the tip of 3D V-notch under creep condition. Its accuracy and advantages compared with plane strain or plane stress solutions are validated. The difference between effective ranges of presented solution and that of plane strain solution is clarified. Moreover, the effect of the creep time on the stress field is also shown. The solutions given in this paper could be beneficial for understanding the 3D effect on notch considering creep loading conditions. Furthermore, the FEM results shows that the proposed 3D solution considering out-of-plane effectagrees better than those of plane-stain and plane stress solutions.

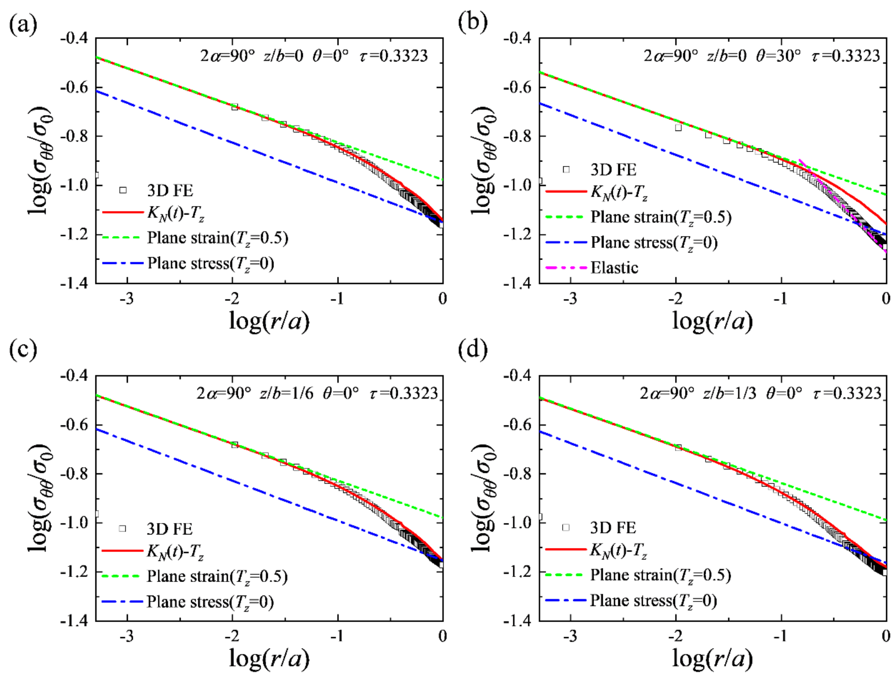

Fig. 3 The radial distribution of circumferential stress of 3D notch of 90°

3. Conclusions

The asymptotic solution considering the out-of-plane constraint effect for 3D sharp V-notch tip field in power-law creeping materials is presented. Asymptotic analysis shows that the stress exponent of sharp V-notches in power-law creeping materials is strongly related to the notch angle, and it increases to zero as the notch angle increases. The stress exponent is significantly affected by the out-of-plane constraint factor. The $K_N(t)-T_z$ solutions are proposed to describe the tip field of 3D sharp V-notch of power-law creeping materials and validated by FEM simulations. Compared with the plane strain or plane stress solutions, $K_N(t)-T_z$ solutions show higher accuracy and a wider effective range for describing the stress field around the 3D notch front, including the out-of-plane stress.

Acknowledgements

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