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Stress and strain concentration factors for tension bars of circular cross-section with semicircular groove

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ABSTRACT

In this paper, the elastic stresses and strains in the circular cross-section bars with semicircular groove subjected to uniaxial tension are systematically examined using the finite element method. It is shown that the stress and strain concentration factors are different even if the material is in the elastic state. Poisson's ratio can have a significant effect on the strain concentration factor. The relation of stress and strain concentration factors is also obtained for stress concentration region in cylindrical coordinates. This relation depends on Poisson's ratio, the radial stress factor and the triaxial stress constraint factor.

1. Introduction

Cracks in structures often initiate and propagate from the locations of stress or strain concentration. Stress and strain concentration locations are the critical structural details to determine crack initiation and growth in engineering structures. The stress concentration problem in round bar with a groove is especially important for test specimens used to investigate the fatigue strength of materials. Exhaustive stress concentration factor figures and tables published by Pilkey and Young account for a wide variety of possible specimen configurations [1,2]. An extensive analysis of grooved bars under a variety of loading conditions was described by an empirical equation which was derived based on theoretical results of semi-infinite plates with a notch [3]. For three-dimensional problems, the stress concentration factors may change with different materials. Poisson's ratio v is often involved in a three-dimensional stress concentration analysis. The influence of Poisson's ratio on the stress and strain concentration factors varies with the geometric configuration. This is because the stress and strain distributions depend on the change of the element volume and the change of the element volume depends on Poisson's ratio. For a hyperbolic circumferential groove in a round bar under tensile load, the stress concentration factors in the axial and circumferential directions are the functions of Poisson's ratio [4]. On the other hand, the stress and strain concentration factors are different even if the material is in the elastic state and the relation of stress and strain concentration factors depends on Poisson's ratio and the triaxial stress constraint factor. Though the effect of Poisson's ratio on stress concentration factor is mentioned in the literatures [5,6], the effect of Poisson's ratio on strain concentration factor and the relation of stress and strain concentration factors are not mentioned for tensile bars of circular cross-section with semicircular grooves.

In this paper, the coupled influences of Poisson's ratio and the geometric configuration upon the stress concentration factor and the strain concentration factor of circular cross-section bar with semicircular groove are investigated using the finite element method. The main purpose of this work is not primarily to provide numerical solutions for certain geometries but to highlight the difference between the stress concentration factor and the strain concentration factor, and the effect of

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Nomenclature

E	Young's modulus
K_t	stress concentration factor calculated from the reference
k_σ	stress ratio
K_σ	stress concentration factor
k_ε	strain ratio
K_ε	strain concentration factor
L	half-length of bar
r_1	radius of semicircular groove
R	radius of the round bar
T_r	radial stress factor
T_θ	triaxial stress constraint factor
x	distance from groove notch root
r, θ, y	cylindrical coordinates
Δ	element length of groove notch root
δ	difference between K_ε and K_σ
ε_{rr}, $\varepsilon_{\theta\theta}$, ε_{yy}	strain components
ε_{net}	mean strain of the grooved section
σ_{y0}	the uniform stress applied on the end of bar
σ_{net}	mean stress of the grooved section
σ_{rr}, $\sigma_{\theta\theta}$, σ_{yy}	stress components
v	Poisson's ratio

Poisson's ratio on stress and strain concentration factors for the tensile bar of circular cross-section with semicircular groove and consequently to provide general advice for this problem.

2. Computational procedure and modeling

2.1. Definition

This study considers a tensile bar of circular cross-section with semicircular groove (see Fig. 1a). The radii of semicircular groove and the round bar are r_1 and R, respectively, and the length of the bar is $2L$. The material is homogeneous, isotropic and elastic. The cylindrical coordinates (r,θ,y) are used in this paper.

The stress and strain ratios are defined, respectively, as

$$k_\sigma = \sigma_{yy}/\sigma_{net} \quad \text{and} \quad k_\varepsilon = \varepsilon_{yy}/\varepsilon_{net}. \tag{1}$$

The stress concentration factor (K_σ) is

$$K_\sigma = \sigma_{yy0}/\sigma_{net}. \tag{2}$$

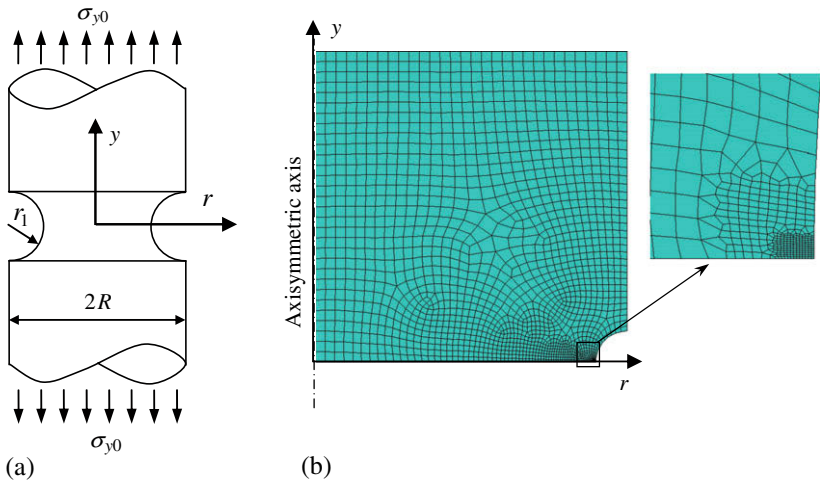

Fig. 1. Illustration of the problem: (a) geometric configuration of grooved bar; (b) the finite element model near the groove root.