Accepted Manuscript

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PII: S0167-8442(17)30002-2
DOI: http://dx.doi.org/10.1016/j.tafmec.2017.09.002
Reference: TAFMEC 1945

To appear in: *Theoretical and Applied Fracture Mechanics*

Received Date: 1 January 2017
Revised Date: 5 June 2017
Accepted Date: 1 September 2017

Please cite this article as: L. Náhlík, K. Štegnerová, P. Hutař, Estimation of critical applied stress for crack initiation from a sharp V-notch, *Theoretical and Applied Fracture Mechanics* (2017), doi: http://dx.doi.org/10.1016/j.tafmec.2017.09.002

Estimation of critical applied stress for crack initiation from a sharp V-notch

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Abstract

The aim of this paper is to estimate the critical applied stress value for a crack initiated from a sharp V-notch tip. The classical approach of linear elastic fracture mechanics (LELM) was generalized because the stress singularity exponent differs from 0.5 in the studied case. The value of the stress singularity exponent depends on the V-notch opening angle. The finite element method was used to determine the stress distribution near the sharp V-notch tip and for estimating the generalized stress intensity factor depending on the V-notch opening angle. The critical value of the generalized stress intensity factor was obtained using stability criteria based on the tangential stress component averaged over a critical distance from the V-notch tip and the generalized strain energy density factor. These criteria were applied in the case of corner stress singularity, as well. The calculated values of the critical applied stresses were compared with the experimental data from the literature, and the applicability of the LEFM concept is discussed.

Keywords: Generalized linear elastic fracture mechanics; V-notch; generalized stress intensity factor, mean stress criterion; critical stress

Introduction

Most engineering structures contain geometrical discontinuities, which relate to the function of the structure. Many of these discontinuities can be treated as notches that cause high stress and strain concentration near the notch root. Due to the nature of the notch, which represents a singular stress concentrator, a crack can initiate from the notch root and, consequently, its existence can lead to the failure of the entire structure. Therefore, the notch behaviour and crack initiation from the notch are of interest to researchers and engineers.

The problem of stress singularities at angular corners was first solved by Williams [1-2] and others [3-4]. Kotousov followed up Williams' works and studied the corner singularities for a sector plate within the first-order plate theory by using stress resultant and displacement functions [5-7] and adapting the eigenfunction expansion approach of Williams [1]. The specificity of the singular stress field near the V-notch have been studied from the experimental side as well; see [8-9] for details. Abundant experimental data exists in the literature devoted to the determination of critical stress for crack initiation from a sharp V-notch. In the past five years, works noting the complexity of the stress field around the notch tip and the influence of out-of-plane singularity caused in the vertex point have been published [10-14]. The knowledge of the stress distribution near the V-notch tip is a basic precondition for estimating V-notch behaviour under specific loading conditions. The V-notch behaviour under static or quasi static loading has been analysed by many researchers (see [15-26]). The problems of cracks and notches have also become the subject of a work of art; see [27] for details.