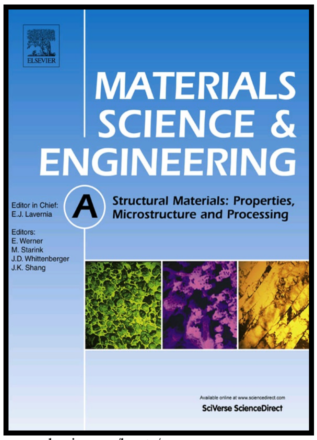
Author's Accepted Manuscript



www.elsevier.com/locate/msea

A New Fracture Criterion for Ductile Materials Based on a Finite Element Aided Testing Method

Y.A.O. Di, C.A.I. Lixun, B.A.O. Chen

PII: S0921-5093(16)30744-4
DOI: http://dx.doi.org/10.1016/j.msea.2016.06.076
Reference: MSA33822

To appear in: *Materials Science & Engineering A*

Received date: 18 March 2016
Revised date: 27 June 2016
Accepted date: 28 June 2016

Cite this article as: Y.A.O. Di, C.A.I. Lixun and B.A.O. Chen, A New Fracture Criterion for Ductile Materials Based on a Finite Element Aided Testing Method *Materials Science & Engineering A* http://dx.doi.org/10.1016/j.msea.2016.06.076

A New Fracture Criterion for Ductile Materials Based on a Finite Element Aided Testing Method

YAO Di, CAI Lixun*, BAO Chen*

Applied Mechanics and Structure Safety Key Laboratory of Sichuan Province, School of Mechanics and Engineering, Southwest Jiaotong University, Chengdu, China

lix_cai@263.net
bchxx@163.com
*Corresponding authors.

Abstract

The fracture criteria for ductile materials have been developed in numerous researches. However there are huge differences between them. Therefore, it's necessary to find a way to select or determine a ductile fracture criterion and identify its applicability and reliability. In this study, a finite element aided testing (FAT) method is proposed to obtain the uniaxial full-range constitutive relationship up to failure of A508-3 steel and SS316L. The fracture stress and strain are obtained based on finite element analysis. A series of tensile tests with different sample geometries and dimensions are carried out to find out the fracture threshold and the critical fracture stress triaxiality σ^*. The experimental and simulation results showed that, the simulated load-displacement curves for all the different type of samples agree with experimental data by introducing the full range constitutive relationship obtained from the FAT method. The fracture threshold of ductile fracture is the first principle stress σ_1. Stress triaxiality σ^* of the specimens changes as the deformation continues. The critical fracture stress triaxiality σ^*_f has the most important influence on the fracture location and fracture threshold of the specimens. Critical fracture process in a wide range of stress triaxiality is investigated based on the finite element simulation process. Thus, a simple logarithmic-relationship between σ_{1f} and σ^*_f has been constructed.

Key words: true stress-strain curve, finite element aided testing method, ductile fracture, stress triaxiality, fracture criterion

1. Introduction

Research in ductile fracture is of great significance on structural integrity assessment issues, forming analysis of cutting, punching problems and damage accident analysis. Ductile fracture depends mainly on two factors: the plastic deformation and triaxial stress state of the material. Plastic deformation capacity of ductile material is mostly affected by temperature and strain rate. Triaxial stress state depends on the structure geometry and boundary conditions of materials. Several studies have shown [1-3] that triaxial stress fracture has a significant impact on ductile fracture. Fracture ductility is understood as the ability of a material to endure a large amount of deformation before fracture. Equivalent strain and principle stress at fracture point are good measurements for fracture ductility.

At present, there are two types of ductile fracture criterion. The first type considers damage accumulation or voids and introducing the damage constitutive equation which establishes the damage and the evolution of the deformation, stress, strain, etc.), such as in the GTN criterion [4-6]. The second type is an uncoupled criterion, which neglects the material yield surface due to the changes in fracture, and considers only the influence of the macro fracture threshold (principal stress, shear stress, equivalent stress and strain, etc.) on critical fracture. This type of criterion has relatively simple forms, less parameters and therefore easier to embed into the finite element software, which is widely used in engineering.

In the early 1950s, Freudenthal [7] put forward the equivalent strain energy criterion, which built a solid foundation for the future development of ductile fracture evaluation. In 1968, ClockCroft and Latham [8] suggested the maximum tensile stress criterion, based on the theory of Bridgeman stress and the results of a series of tensile test. Fracture occurs when local maximum tensile stress of energy accumulation reaches the critical value. Mcclintock [9], Rice and Tracy [10] studied the deformation behavior of holes in different stress state, and brought up a fracture criterion considering the effects of stress triaxiality σ^*. This is the first application of stress triaxiality σ^* on fracture criterion. In 1972, Oyane considered the effect of hydrostatic pressure on fracture criterion and proposed the Oyane criterion, which can better describe some breaking problems [11]. At the same time, Brozzo also proposed a fracture criterion in consideration of hydrostatic pressure on fracture criterion [12].

In 1976, Mr. OH took equivalent stress into account in C&L and proposed the modified C&L criterion. In 1977, Gurson applied damage in the yield equation and put forward the Gurson model [4]. In 1978, Norris considered the effect of hydrostatic pressure accumulation and put forward the Norris model. After considering the hydrostatic pressure, a new criterion considering asymmetric strain criterion weighted coefficient was given by Wilkins[13]. Table 1 shows the mentioned model of fracture criterion, time proposed and the name of the criterion.