Materials and Design 32 (2011) 2066–2072

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

A proposed maximum ratio criterion applied to mixed mode fatigue crack propagation

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ARTICLE INFO

Article history:
Received 12 August 2010
Accepted 23 November 2010
Available online 27 November 2010

Keywords:
Fracture
Criterion
Maximum stress ratio

ABSTRACT

In the present paper, the crack initiation and propagation in rectangular magnesium alloy plates containing an inclined through crack are investigated experimentally and theoretically. Based on the complex stress state at the crack tip, a maximum ratio criterion is developed to determine the crack propagation for a given inclination angle by means of an opening mode theory. It is assumed that the crack begins to propagate when the maximum value of ratio approaches its critical value, and the direction of crack propagation coincides with the direction of maximum ratio defined. The experiments for checking the theoretical predictions from the proposed criterion have been conducted. The material properties and fracture characteristics are evaluated during the tests. The results obtained are compared with those obtained using the commonly employed fracture criteria and the experimental data.

1. Introduction

In practical situations, structural members are often subjected to three-dimensional stresses, which cause mixed mode fractures consisting of opening, in-plane sliding and out-of-plane sliding modes. Mixed mode or inclined surface crack is one of the most common failure forms of engineering materials, and is commonly encountered in dealing with engineering structures [1–5]. The study of mixed mode fatigue crack propagation examines how a fatigue crack initiates and grows under cyclic load. This topic is mainly dealing with the development of various models to better explain the crack propagation phenomenon [6–8]. Much research in this field has been done and some criteria for predicting fatigue crack propagation have been set up by means of energy principles and the stress approach. Earlier investigators, particular Griffith [9], reasoned that crack propagation occurs when the elastic energy stored in the structure overcomes the surface energy of the material. This criterion is only defined for mode I loading and assumes the direction of crack initiation as a priori. Hussain et al. [10] suggested a maximum energy release rate criterion based on the Griffith energy principle. It is assumed that crack extension occurs when G_{max} reaches a critical value G_{cr}, where G_{max} is the energy release rate G for crack extension in such a direction that makes G maximum. Sih [11,12] established the minimum elastic strain energy density criterion. This criterion assumes that the crack initiation takes place along the direction with the minimum strain energy density around a crack tip and a crack extension starts in the initiation direction when strain energy density reaches a critical value. Erdogan and Sih [13] gave a maximum tangential stress criterion, i.e., $\sigma_{\theta,max}$-criterion. The criterion shows that the crack initiation direction coincides with the direction of the maximum tangential stress on a spherical surface with the constant strain energy density ahead of the crack tip. However, the comparison shows that there exists a large difference between the results from these fracture criteria and experiments. Therefore, it is necessary and very useful for mechanics researchers to establish a reliable criterion for practical engineering structures.

The magnesium alloys exhibit excellent mechanical properties, such as high specific strength at a room temperature and superplasticity at an elevated temperature [14,15]. They have high potential for use in motor vehicle components, because of their relatively low density, good damping characteristics, dimensional stability and machinability. These attributes make magnesium alloys an economical replacement for many types of zinc and aluminum die castings, as well as for cast iron and steel components in motor vehicle assemblies. In the present analysis, the behavior of fatigue crack propagation of rectangular AM60B magnesium alloy plates, each consisting of an inclined through crack, subjected to axial loading is investigated theoretically and experimentally. The results of mixed mode fatigue tests on specimens with different inclined starter notches are presented. The inclined angle of the crack with respect to the axis of loading varied between 0° and 90°. It is evident that the crack propagation path cannot be predicted without having the knowledge of crack initiation and subsequent

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doi:10.1016/j.matdes.2010.11.053