ACOUSTIC EMISSION STUDIES OF SLOW CRACK GROWTH IN Zr-2.5% Nb

by

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ABSTRACT

The detection and analysis of 'Acoustic Emission' is one of the most promising non-destructive techniques to be used as an integrity monitoring device. The technique has the ability to detect the crack formation and its growth, at the time it occurs, and to accomplish this remotely.

Acoustic emission could be classified as low amplitude acoustic signals emanating from processes involving small amounts of energy such as plastic deformation, twinning, slip or sudden reorientation of grain boundaries and as high amplitude signals from micro/macro cracking, fatique, stress corrosion cracking, and hydrogen embrittlement, etc. Dealing with high amplitude signals, as they are easy to handle with respect to the noise level of the system, the AE has a vital potential to monitor sub-critical crack growth.

The mechanism in Zr, Ti and Va alloys involves discontinuous crack extension through hydride particles formed at certain temperatures in the presence of available hydrogen and is usually termed as delayed hydride cracking. AE was successfully monitored for slow crack growth during delayed hydride cracking in Zr-2.5% Nb alloy. The results indicate that the quantitative measurements of crack extension and crack velocity, which is of the order 10^{-9} to 10^{-11} m/sec, are possible using acoustic emission technique. Furthermore, AE tests support the suggested fracture mechanism in this alloy.

The effects of stress intensity, temperature and hydrogen content have been studied on acoustic response of slow crack growth and discussed accordingly. The total number of counts and the burst count rate were found to be in direct proportionality with the area cracked during slow crack growth and the crack velocity respectively.

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1. INTRODUCTION

Slow crack growth has been observed in various materials such as steels, nickel, Ti, Va, Zr, etc. under hydrogen embrittlement. Stress corrosion cracking and fatigue. Various techniques have been employed to measure crack velocity during slow crack growth in these materials. One of the most common techniques for such measurements involves the use of COD (crack opening displacement) gauge. The technique provides reasonably reliable data as far as crack velocity measurements are concerned. However, COD measurements reflect only the cumulative effect of all crack growth events in the thickness, i.e. the macroscopic crack growth. (The use of COD gauge also involves specimen standardization and calibrations). Optical method has been used to monitor the moving crack tip by employing a travelling microscope. This method reveals only the surface effects and cannot be used in the case of plain strain fracture toughness tests where the crack growth is more dominant at the centre of the specimen. This method may also produce erroneous results where the crack branching is associated with the crack tip movement. Other researchers[1,3] have used a post-mortem type of technique where the specimen is fast fractured after the test and the incremental crack growth optically measured. This technique is very time consuming and measures only the cumulative growth for a certain length of time. The above techniques suffer from a common handicap, namely, their limited potential in determining the details of the fracture mechanisms involved.

In this study, acoustic emission has been advantageously used for the detection and continuous surveillance of propagating cracks in Zr-2.5% Nb. An AE testing system has been developed to test fatigue precracked compact tension specimens and AE signals from slow crack growth have been analyzed. The AE count rate provided quantitative measurements of crack growth rates while totalized AE (burst*) counts estimated the incremental area cracked. The nature of AE plots from the slow crack growth indicated that the crack growth process was discontinuous and involved local embrittlement. The absence of AE bursts at temperatures above 200°C in isothermal SCG test indicate the requirement of hydride particle for crack growth to occur. These observations confirmed the basic models of slow crack growth in this material suggested by AECL researchers[42-46]. Effects of stress intensity factor, temperature and hydrogen content were studied and have been discussed accordingly. Supplementary fractographic studies employing optical, scanning and transmission electron microscopes were carried out on AE tested specimens. These studies further confirmed the conclusions that the crack growth process is intermittent and involves hydride cracking.

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* See Appendix C

2. LITRATURE SURVEY

2.1 Acoustic Emission

Acoustic emission is a natural concomitant of any dynamical process. The stored potential energy during straining of the material is released during deformation and fracture. Part of this energy is transformed into elastic waves that propagate through the material and may be detected on the surface by a sensitive transducer. Such signals are called acoustic signals, stress wave emissions or seismic signals. These emissions are high frequency (10 KHz to 5MHz), short time (.03 to 30 μsec) pulses which reflect the response of the material under deformation.

Characteristically, all metals exhibit two distinct types of emissions[23,25,30] referred to as burst type and continuous type (Fig. 1). As observed on the oscilloscope screen, the burst type signal appears as an exponentially decaying ring down pulse, with relatively high amplitude whereas the continuous signal has an appearance of sustained signal level with relatively low amplitude. The two emissions are produced depending on (1) AE response of the material, e.g. zinc emanates predominantly burst type while Aluminum almost entirely continuous signals; (2) type of deformation, e.g. micro/macro cracking and fracture result in burst type while yielding and plastic deformation produce continuous emissions. A large number of investigations have been reported on AE generation during