Engineering Failure Analysis 18 (2011) 1333–1340

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Failure probabilistic analysis of steam generator heat-transfer tubing with pitting corrosion

B.H. Zhou [a,*], Z.Q. Zhai [b]

[a] School of Mechanical Engineering, Tongji University, Shanghai 201804, PR China
[b] School of Mechanical Engineering, Shanghai Jiaotong University, Shanghai 200240, PR China

ARTICLE INFO

Article history:
Received 11 August 2010
Received in revised form 25 March 2011
Accepted 28 March 2011
Available online 2 April 2011

Keywords:
Failure probability
Pitting corrosion
Non-homogenous Poisson process
Gamma process
Likelihood function

ABSTRACT

Pitting corrosion damages seriously steam generator (SG) heat-transfer tubing of nuclear stations. To estimate accumulative failure probability of the SG heat-transfer tubing, a failure probabilistic analysis method with pitting corrosion of stochastic processes is proposed in this paper. Pitting corrosion can be considered as a combination process of pit initiation and growth. The pit generation process is built as a non-homogenous Poisson process. The pit growth process is modeled by a stationary gamma process. A cumulative failure probability model is derived from the stationary gamma process. The proposed model is evaluated with the maximum likelihood estimation method according to the experiment data. Finally, Monte Carlo method is applied to simulate the cumulative failure probability model. The results illustrated that the proposed method is feasible and practical to estimate the accumulative failure probability of the SG heat-transfer tubing.

1. Introduction

Steam generator (SG) heat-transfer tubing is a crucial part of the nuclear water reactors. Due to interaction with the surrounding chemical environment, the SG heat-transfer tubing has been subjected to a number of deterioration and degradation modes [1,2]. Pitting corrosion is a serious form of degradation in the SG heat-transfer tubing of some nuclear power plants. Pitting corrosion is characterized as an extremely localized attack on the metal surface resulting in small cavities or holes. Under-deposit pitting is a special case of crevice corrosion where hostile ions in the scale, sludge deposits are concentrated to aggressive levels on the outside diameter of the SG heat-transfer tubing, resulting in metal dissolution and pit formation [3]. It is difficult to deal with pitting corrosion of the SG heat-transfer tubing because of its complex nature. Therefore, it is a challenge to develop theoretical models and simulation methods for a better understanding of the results of the pitting corrosion process of the GS heat-transfer tubing.

It is now widely recognized that pitting corrosion has a stochastic nature [4]. Shibata pointed out that it is difficult for lifetime estimation of structures affected by localized corrosion unless the stochastic approach is introduced [5].

Many stochastic models of pitting corrosion have been developed and summarized in last decades. A homogenous Poisson process was proposed to describe the pit initiation process. In this way, the distribution of pit nucleation times can be simulated using the exponential and the Weibull distributions [4,5]. Provan and Rodrguez presented a non-homogenous Markov process to model pit depth growth for the first time. They compared the estimated results with the experimental data reported for aluminum and their own pitting corrosion experiences conducted on stainless steels [6]. Wu and Ni pointed out that a Markov chain model with a transition probability matrix based on statistical data does not accurately

* Corresponding author.
E-mail address: bhzhou@tongji.edu.cn (B.H. Zhou).

1350-6307/$ - see front matter
doi:10.1016/j.engfailanal.2011.03.022