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Mechanical properties and eddy current testing of thermally aged Z3CN20.09M cast duplex stainless steel

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Abstract

To study the thermal aging embrittlement of Z3CN20.09M duplex stainless steel produced in China, accelerated thermal aging experiments were carried out at 380℃ up to 9000h. Microhardness measurements, Charpy impact and eddy current tests were performed on aged samples to characterize their thermal aging embrittlement. The results showed that the signal amplitude of eddy current decreased with the increase in aging time. Two quantitative correlations of the eddy current signal amplitude with both the Charpy impact energy, and the Vickers microhardness of the ferrite phase are obtained. The study showed that eddy current testing could be used to non-destructively evaluate the thermal aging embrittlement of cast duplex stainless steels.

Keywords: Thermal aging embrittlement, Cast duplex stainless steel, Eddy current testing, Microhardness, Charpy impact energy.

1. Introduction

Cast duplex stainless steels (CDSSs) used as primary coolant water pipe in pressure water reactor (PWR) are susceptible to thermal aging embrittlement at operating temperatures from 280 to 320℃ [1]. The mechanism of this embrittlement is associated with both spinodal decomposition and precipitation of G phase in ferrite phase [2-4], which may seriously affect the safety of nuclear power plants [5]. There is still no reliable inspection technique to this kind of embrittlement of the CDSS pipes, especially for the in-service integrity inspection of CDSSs. Several studies have been performed on the development of the non-destructive characterization of the thermal aging embrittlement occurred in the CDSSs. Albuquerque et al. [6] have found that the sound speed of the duplex stainless steel UNS S31803 has evidently changed during thermal aging treatment at 425℃, and they suggested the use of sound speed to evaluate the mechanical property variation. Chandra et al. [7] have investigated the thermal aging effects of the duplex stainless steel UNS S32205, using a double loop electrochemical potentiokinetic reactivation test, and obtained a linear correlation between mechanical and electrochemical behavior.

Eddy current (EC) testing is a well-known non-destructive method, widely used to inspect the metallic materials in engineering applications. An EC testing gives a signal, which is closely related to the electrical conductivity and magnetic permeability of the tested materials. Therefore, any kind of changes in material microstructures could be detected by the EC testing in case of any changes of electric and/or magnetic properties of the materials. Previous researchers [8-10] have