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Failure analysis of a pressure vessel bolt in a nuclear fuel fretting wear simulator

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ABSTRACT

This paper presents a failure analysis on a pressure vessel bolt of a fretting wear simulator. After 500 h tests, in an upper pressure vessel of a fretting wear simulator, one bolt among eight was fractured near the bolt neck regions. The fracture surface was examined by using a scanning electron microscope (SEM) to determine the failure initiation and failure mode. The result indicates that the fracture surface shows intergranular fracture features. Based on the mechanical property data of a bolt material, it is concluded that the exerted stress on the bolt applied by an internal pressure of the pressure vessel has a negligible effect on the major failure causes. In order to verify the mechanical properties of the fractured bolt, tensile test has been performed and its result was compared with material specification. As a result, it is thought that both excess heat treatment during the surface hardening procedure and loose parts in the thread hole have significant effects on the pressure vessel bolt failure. In this paper, the reasons for this failure were discussed by using metallographic studies of the failure surface, mechanical tests with the failed bolt and the stress distribution of the contact regions with considering loose parts by using FE analysis.

1. Introduction

A vertical type of a fretting wear simulator for high temperature and pressure water condition was developed for evaluating the fretting wear behavior of nuclear components [1]. This simulator was applicable to the evaluation of fretting wear damages due to a flow-induced vibration (FIV), which have been experienced in relatively slender structures such as nuclear fuel rods, steam generator tubes and control rods [2]. After 500 h test, however, one bolt among eight was fractured near the bolt neck regions in an upper pressure vessel as shown in Fig. 1. Considering the system performance at high temperature and pressure conditions, the reliability of the pressure bolt should be sufficiently satisfied during services. In this study, the failed bolt was inspected to identify the reasons for the rapid rupture. The possible failure causes were assessed and discussed by using SEM observation of the fracture surface, measurement of the micro-vickers hardness, tensile test with the failed bolt and stress analysis of the pressure vessel bolt with considering loose parts in the thread hole.

2. Investigation methods

The failed pressure vessel bolt used in this simulator is a conventional high-carbon martensitic stainless steel (SUS 440C). This material is widely used as tools or blades in relatively corrosive atmospheres [3]. After machining to fit the system performance, these bolts were heat-treated in order to increase surface hardness for preventing the thread wear of the bolt

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