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Erosion corrosion in stainless steel pipe under water vapour two-phase flow conditions

Mitsutaka H. Koike *

Safety Promotion Project, Japan Nuclear Cycle Development Institute, 4-49, Muramatsu, Tokai, Naka, Ibaraki 319-1184, Japan

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Abstract

High-speed two-phase water vapour flows in the outlet portion pipes of nuclear power stations. Erosion corrosion experiments of stainless steel were performed by the use of Component Test Loop, in which high-temperature pressurized water vapour is circulated, under test conditions of all volatile treatment with steam phase velocities 10–40 m/s (steam quality 15%). The erosion corrosion losses were estimated by weight differences of pipe specimens before and after tests. Erosion corrosion losses are very small and almost constant for velocities of two-phase flow.

Keywords: Stainless steel; Erosion; Reactor conditions

1. Introduction

Japan Nuclear Cycle Development Institute has developed the ATR-Fugen, a 165 MWe prototype boiling-light-water-cooled heavy-water-moderated pressure-tube-type reactor of Japan, which has operated satisfactorily since the start of

* Tel.: +81 29 282 1122; fax: +81 29 282 4921.
E-mail address: mhkoike@hq.jnc.go.jp

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commercial operation in March 1979. The ATR is a unique reactor designed mainly to use plutonium–uranium mixed oxide fuels.

A 600 MWe ATR Demonstration Plant has been designed on the basis of the experience of the Fugen. The demonstration reactor has 648 outlet pipes in which high-speed two-phase water (≈280 °C, 7 MPa) flows from pressure tube to steam drum. The outlet pipes are made of type 316 stainless steel and about 3 in. in size. The design value of average steam phase velocity of two-phase flow in the outlet pipes is about 14 m/s, and the maximum velocity is about 20 m/s. Design values of the average and maximum steam qualities in the outlet pipes are about 16% and 30%, respectively. It must be certified that outlet pipes are endurable under these conditions throughout the life of the reactor operation.

There have been few erosion experiments and theories under water vapour two-phase flow for steam qualities of 10–30%. Therefore, erosion corrosion experiments of type 316L stainless steel are conducted in this work under water vapour high-speed two-phase flow conditions, with parameters of flow speed by the use of Component Test Loop (CTL). The CTL is a full-scale test facility simulating the primary cooling circuit of the ATR in terms of coolant temperature and pressure.

Ito [1] performed erosion corrosion experiments of stainless steel under high-temperature water with velocity of 1–12 m/s. Okada [2] performed cavitation erosion tests by water for carbon steels. Investigations were performed by Palomero [3] on erosion corrosion of steam generator tubes of nuclear power station. As for the theory, Thiruvengadam [4] derived an equation on a threshold criterion of erosion. Springer [5] proposed an equation which represented incubation time for erosion under liquid droplets. However, these investigations were performed on erosion corrosion of materials under single-phase flows. In respect of the erosion corrosion under water vapour two-phase flows for steam qualities of 10–30%, there are few erosion corrosion experiments and also few erosion corrosion theories. This paper describes erosion corrosion experimental results and the discussion, under water vapour two-phase flow conditions using a big testing apparatus.

2. Experimental procedure

Erosion corrosion experiments were performed by the use of the CTL in which high-temperature pressurized two-phase water vapour is circulated. Fig. 1 shows the schematic flow diagram of the CTL. Maximum pressure and temperature of the CTL for use are 8.1 MPa and 297 °C, respectively. Maximum water flow rate and steam flow rate are 120 and 15 t/h, respectively. A boiler supplies heat to water and circulation pumps supply head to water in the CTL. Water vapour two-phase flow is produced by mixing hot water and steam. After they are mixed, the two-phase water vapour flows into erosion corrosion test sections and to a Direct Condenser which separates vapour from two-phase flow. Vapour is circulated by a Steam Compressor with high speed. There are three test channels in the CTL, two of which abbreviated in the figure are used for another tests as fuel assembly endurance test, seal plug test and pressure drop test.