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Experimental Study on the Influence of the Supporting Condition and Rod Motion on the Fuel Fretting Damage

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ABSTRACT

Fretting failure of a nuclear fuel is a wear that occurs on the contact between the spacer grid springs/dimples and fuel rods. A perforation may occur in the furl rod cladding tube due to a severe wear. It results in an increase of coolant radioactivity level, which is strictly regulated in the nuclear power plant operation. The fuel fretting study is currently one of the key issues for enhancing the fuel reliability since a failure due to it occurs continuously and even tends to increase reflecting the demand of a high burn-up fuel by the utilities. However, it is a difficult task since the study on it is multidisciplinary such as tribology, contact mechanics, vibration analysis (including the FIV, i.e. flow-induced vibration) etc. Experimental as well as theoretical study is highly necessary to simulate and investigate actual conditions causing wear. Such conditions include a supporting condition between the fuel rods and grid springs/dimples, fuel rod motion due to the FIV, the shape of the spring/dimple especially at the contacts with the rods and the characteristics of them. These are termed as mechanical parameters in this paper. For instance, a gap formation between the rods and springs/dimples is associated with the increase of vibration amplitude and the change of wear mechanism. The trace of a rod in a perpendicular plane to the fuel axis affects the wear shape and severity.

Present study focuses on the influence of the mechanical parameters on the fuel fretting wear through experiments using a self-developed wear simulator, which has been introduced at the Water Reactor Fuel Performance Meeting, Kyoto Japan in 2005. In the experiment, fuel rod specimen of two span lengths is vibrated by two perpendicularly aligned electromagnetic actuators. Both ends of the rod specimen are supported with a positive contact force and the variation of the supporting condition is simulated by moving each of four grid strap specimens constituting a grid cell (1×1) at center. Experiments are carried out under the room temperature and distilled water condition. As for the conditions of the mechanical parameters, 0.2 mm gap and 10 N force are used for the supporting condition; a circular and a diagonal traces are applied for the rod motion. The contact shape of the spring/dimple is concave intending to increase the contact area. Both the spring/dimple and fuel rod specimens were fabricated from the as-received materials (zirconium alloy) for a commercial fuel assembly. Experiment of each condition is carried out for 72 hours. Wear volume, area and depth on the cladding tubes are examined.

As a result, present concave shaped spring/dimple causes less wear when the rod moves in a circular manner than a diagonal one if there is a positive contact force (10 N). In the case of a gap existence (0.2 mm), however, a diagonal motion is more detrimental to wear. Wear amount at the spring and dimple is influenced by the location of them and the rod motion. It is found that wear is concentrated at the contact edges between the spring/dimple and rods due to the contact shape. The influence of the rod motion on the worn area and its shape is also discussed.

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