The Spent Fuel Integrity during Dry Storage
– An Evaluation of Hydrogen Migration in Cladding Existing Axila Temperature Gradient –

Background

At present, spent nuclear fuels coming from nuclear plant are stored at reactor site areas before shipment to reprocessing plants. Japanese government and electric utilities have a plan to operate interim dry storage facilities away from reactor sites till 2010. An experiment using the real spent fuel cladding and following evaluation of fuel integrity focused to dry storage is necessary prior to the start of operation of the interim dry storage facilities away from reactor sites.

One of the phenomena that will affect fuel integrity during the dry storage is the migration of hydrogen in cladding in the axial direction. If there is a hydrogen pickup in cladding at irradiation, hydrogen will move from hotter to colder cladding region in the axial direction under fuel temperature gradient during storage and will be precipitated as hydride, and consequently hydride brittleness may take place in the cladding (Fig.1).

Objectives

To carry out the experiment focused to hydrogen migration relating to hydride brittleness and obtain the data to evaluate the hydrogen migration by using real twenty years dry (air) stored spent PWR-UO_2 fuel rods. To evaluate a hydrogen distribution in the cladding after dry storage by calculation.

Principal Results

The hydrogen diffusion coefficient, the solubility limit of cladding and the heat of transport of hydrogen that relates to migration caused by temperature gradient are necessary to evaluate a hydrogen migration in the cladding during storage. To obtain these data, the hydrogen migration experiments were carried out on the real twenty years stored PWR-UO_2 fuels (burn-up: 31MWd/kgHM and 58MWd/kgHM) and hydrogen distribution in the cladding after dry storage was predicted by the calculation.

(1) The hydrogen concentration measurements were carried out on cladding specimens after hydrogen migration experiment (Fig.2). In this study, the heat of transport, diffusion coefficient and solubility limit of real stored spent fuel cladding, whose data were none or few, were obtained by fitting the hydrogen flux equation based on Fick's law to hydrogen concentration distribution obtained by measurement. The heat of transport of irradiated cladding was significantly larger than that of unirradiated cladding. This means that hydrogen in irradiated cladding can move easier than that in unirradiated cladding (Table 1).

(2) There are few differences in the diffusion coefficients and solubility limits between the irradiated cladding and unirradiated cladding (Fig.3). The conservative safety evaluation on hydrogen migration can be possible using the diffusion coefficient and solubility limit of unirradiated cladding.

(3) The hydrogen distribution in the cladding after dry storage for forty years was evaluated by one-dimensional diffusion calculation using the measured values. In calculation, the maximum values as the heat of transport, diffusion coefficient and solubility limit were selected to evaluate conservatively. The axial hydrogen migration was not significant after dry storage for forty years in helium atmosphere, except at fuel rod ends (Fig.4).

It is concluded that hydrogen migration has few effect on the fuel integrity during dry storage.

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Reference

A.Sasahara, T.Matsumura, "Post irradiation experiments of twenty years stored spent fuels", Storage of Spent Fuel from Power Reactors, IAEA, 2003, June 2-6, Vienna.

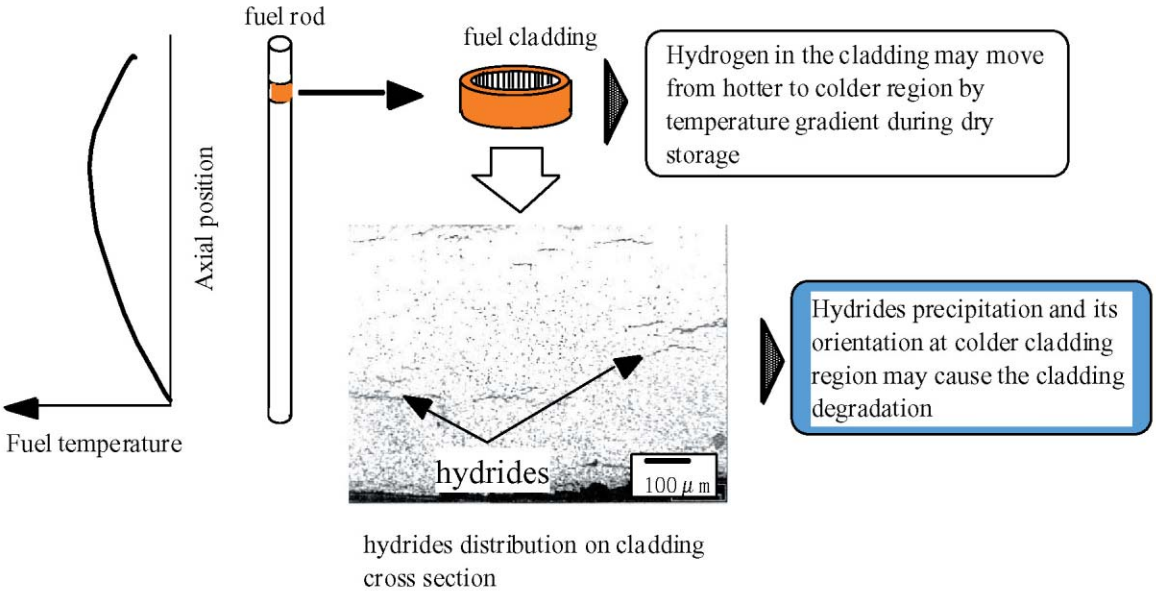

Fig.1 Effect of hydrogen on spent fuel cladding

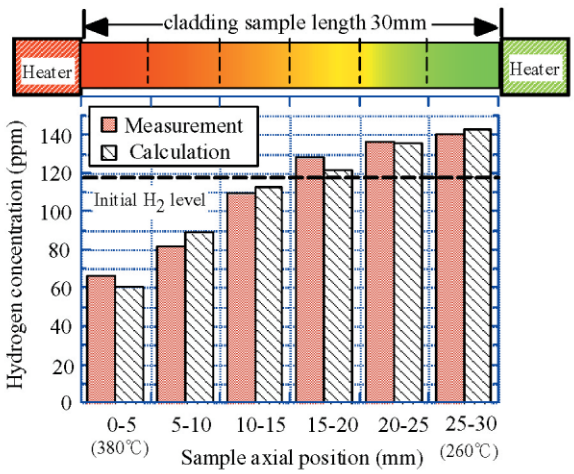

Fig.2 Hydrogen concentration in the irradiated cladding after migration experiment

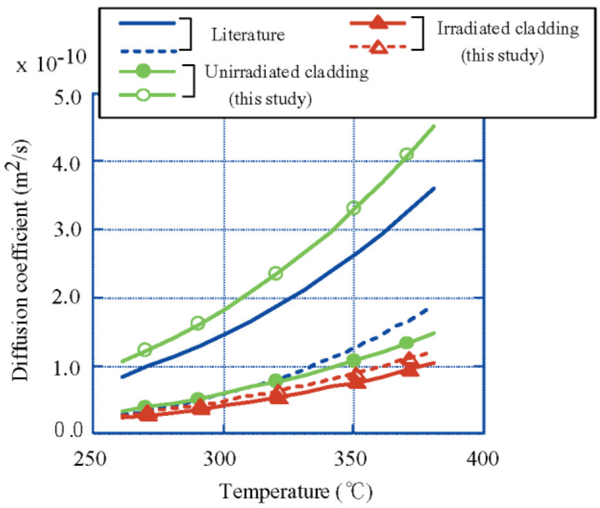

Fig.3 Diffusion coefficient of irradiated and unirradiated cladding

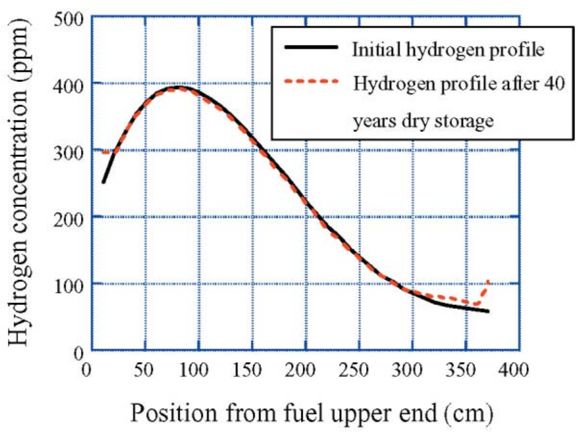

Fig.4 Hydrogen distribution by calculation in the cladding after forty years storage

Table 1 The heat of transport obtained by this study

Sample	Heat of transport (kcal/mol)
Unirradiated cladding	4.5～9.7
Irradiated and stored cladding	10.6～17.7