Priority Subjects — **Establishment of Optimal Risk Management**

Development of Long-Term Storage Management Technologies for Spent Fuel

Background and Objective

The interim storage of spent fuel by the operation delays of reprocessing facilities serves the important purpose of time adjustment. Up until now, storage using metal casks has been put to practical use, but there are now expectations regarding the practical use of concrete casks from the viewpoint of diversification of storage technology and economic efficiency. Moreover, in response to an increase in demand for radioactive material transportation, there is hope that a new shock absorbing material will be developed to substitute wood, which has been used conventionally.

For the practical use of concrete cask storage, we establish a preventive technology and defect detection method by Non-Destructive Inspection for the stress corrosion cracking (SCC) of the welded parts of the metal canisters used for storing spent fuel and propose a related society standard.

In addition, we examine the applicability of foaming urethane material as a new shock absorbing material for the transportation packaging of radioactive materials.

Main results

1 Verification of preventive measures against SCC occurrence by shot peening

We examine an application of zirconia shot peening (ZSP)* as residual stress improvement processing that is considered to prevent SCC occurrence effectively at the welded part of a canister. As a result of having performed ZSP processing to a full-scale model of canister made of SUS304L, the residual tensile stress in the vicinity of the weld turned to compressive stress in the range of approximately 0.7mm in depth (Fig. 1). In addition, as a result of having carried out SCC examinations for more than 2,000 hours at a temperature of 80℃ and a relative humidity of 35% which are severer conditions than an actual marine environment (temperature of 50℃, relative humidity of 35%), a high number of cracks larger than 100μm occurred in the vicinity of the weld where ZSP was not applied, but cracks were not observed in the area that was processed by ZSP, thereby its effectiveness was confirmed. (N12023)

2 Development of a measurement technique for salt deposits on the surface of canisters for an SCC countermeasure

Since chloride is considered a factor behind the occurrence of SCC, we develop a technique to measure chlorine deposited on the surface of canisters by laser-induced breakdown spectroscopy (LIBS). Although LIBS is expected to measure chlorine concentration with high precision, tensile residual stress may be induced in the metal surface because of laser irradiation and may affect SCC initiation. Therefore, the laser pulses were irradiated on a specimen of canister candidate materials type 304L with typical conditions for LIBS measurement, and we evaluated its influence on SCC occurrence. The tensile residual stress in the irradiated point after laser irradiation ranged around 65μm in depth, and the depth of cracks considered to be SCC occurred due to the corrosion test were 10-40 μm, which is very small compared to the thickness of the canister (12.7mm). Thus, it is considered that there was little influence of the laser irradiation on the SCC (Fig. 2); (H12003).

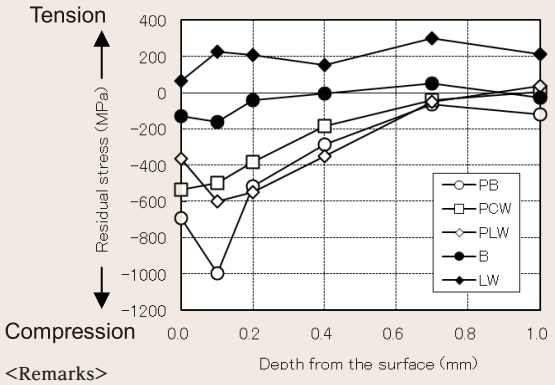
3 Proposal for the Japan Society of Mechanical Engineers standard of Concrete Cask [Non Destructive Inspection method on the weld part of the canister]

Based on results of our research on a Non-Destructive Inspection method to weld part of the canisters and the discussions of the expert committee set up in CRIEPI, we proposed a revision plan of "spent fuel storage facility construction code, JSME S F B 1-2003" to the Japan Society of Mechanical Engineers. Non-Destructive Inspection necessary for every steel grade after having classified the available materials for canisters into austenitic stainless steel and two-phase stainless steel was proposed (Table 1).

4 Development of new shock absorbing material for the transport package

We focused on rigid polyurethane foam (hereinafter “R-PUF”) as a substitute material for woods used as a shock-absorbing material and built a database of the stress-strain characteristics through a compression test in which density, deformation rate and temperature are considered as parameters. Furthermore, we carried out drop tests stipulated in transport regulation using a cask of a reduced scale with shock absorbers made from R-PUF. The results of this test confirmed that R-PUF was applicable as a shock-absorbing material as the acceleration generated at the cask was less than the design value (Fig. 3); (N12020).

* A metal surface treatment which hits the surface of a device with small zirconia grains to give compressive residual stress.



<Remarks>
ZSP applied: PB (base material), PCW (weld in a circumferential direction), PLW (weld in a longitudinal direction)
ZSP not applied : B (base material), LW (weld in a longitudinal direction)

Fig. 1: Stress state improvement by the method of ZSP

Residual stress improvement was carried out on a canister with a full-scale diameter size using zirconia shot peening (ZSP) in the area close to the weld.
Tensile stress was generated in the range of 1mm depth when only grinder processing on the surface was applied after welding, but compressive stress at a depth of 0.7mm from the surface was generated by applying the residual stress improvement using ZSP and its effectiveness was confirmed.

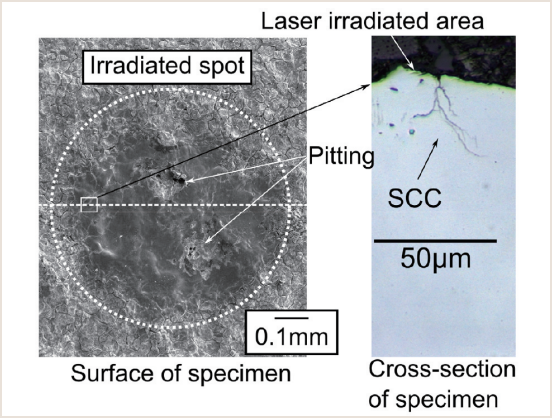


Fig. 2: Results of a corrosion test of the specimen irradiated by a laser pulse

Synthetic seawater was dropped on a specimen irradiated by a laser pulse (wavelength: 532nm, pulse width: 10ns); the specimen was set up under the environmental conditions in which SCC occurs.
As a result, cracks considered to be pitting and SCC were observed, but crack depth was extremely small. We confirmed that the laser irradiation effect on SCC propagation was negligible.

Table 1: Summary of a revision plan for a Non-Destructive Inspection method on the welds of canisters*

Materials	The weld crack concerned [a]	Penetration test (PT)[b]	Ultrasonic test (UT) [c]	Remarks
Austenitic stainless steels	Hot Crack	Required [d]	Not Required [e]	・An inspection interval is required every 1/4tw which is the setting grounds of the stress reduction coefficient (tw: Welding thickness) ・Text revision
Two-phase stainless steel	Cold crack	Required [d]	Required [f]	・Demand of UT for the purpose of exclusion of the cold crack due to the non-fusion part ・UT is prescribed as a new code case

a)Materials targeted for the standard are divided into two steel grades in consideration of the cracks for which there is concern about for welding and appropriate non-destructive testing is applied to each.
b)Method to detect flaws on the surface from the patterns after penetrating and wiping off an indicator applied to the surface.
c)Method to detect a defect inside the body from the reflection wave of an ultrasonic wave which was generated from a probe pressed against a weld.
d)Increase the inspection number of times than the current rule even for the same welding thickness by reducing the distance for PT.
e)The cracking which is causing concern can be detected by PT
f)UT is also required because the cracking for which there is concern might progress after the PT.

*CRIEPI proposes to Japan Society of Mechanical Engineers

Fig. 3: Accelerations at the drop test of the reduced scale model

Drop tests were carried out from a 9m height onto a rigid target using a 1/3 reduced cask with shock absorbers made of rigid polyurethane foam.
The maximum acceleration generated in the cask during the drop test was less than the design value, confirming that rigid polyurethane foam has enough performance as a shock absorbing material.