Static Characterization of Spacer Grid with Chrome-Coated Nuclear Fuel Rod Inserted

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***Keywords :** static buckling, grid, chrome-coated fuel rod, accident tolerant fuel

1. Introduction

The development of SMR technology has progressed globally, and the SMR fuel and control rod technology has also been developed domestically.

Innovative SMR(i-SMR) nuclear fuel with improved accident resistance and seismic performance, and innovative SMR control rods that provide sufficient shutdown margin throughout the entire cycle, have been developing. These innovations will include the accident tolerant fuel design technology and it can prevent or significantly delay the occurrence of major accidents such as the Fukushima nuclear accident, enabling proactive response and innovative nuclear safety.

The purpose of static buckling test is to verify the clamping loads for fuel assembly manufacturing and shipping and to obtain the through-grid stiffness for both conditions against the adjacent fuel assembly or reduced support of the core shroud.

Many studies have been conducted to simulate the mechanical behaviors of spacer grids, including their static and dynamic buckling strengths and impact response characteristics [1, 2, 3]. The fuel rods inserted into the spacer grid affect the static characterization of spacer grids. Thus, this study has researched the static characteristics of the nuclear fuel grid with chrome-coated fuel rods inserted.

2. Methods and Results

2.1 Accident Tolerant Fuel Rod

The accident tolerant fuel rod consists of a HANA-6 cladding tube coated with chromium to a thickness of about 15 ㎛ on the outer surface of the cladding tube and a LAS doped UO_2 sintered with elements added to suppress fissile material release and enhance high temperature plastic deformation properties. The main parameters of the chrome-coated tube and the conventional zirconium tube are shown in Table 1 and Table 2.

Table 1: Elastic Modulus of Fuel Rods Materials (Ratio)

	Conventional Zirconium Alloy	Cr-Coated HANA-6
Room Temperature	1	0.95

Table 2: Outer Diameter of Fuel Rods (mm)

	Conventional Zirconium Alloy	Cr-Coated HANA-6	Coating Layer
Outer Diameter	9.5	9.53	0.015

2.2 Test Specimens and Equipment

The tests were conducted at room temperature. The grids for static buckling test were performed with two conditions, such as beginning of life (BOL) and end of life (EOL). In order to simulate the EOL condition, the grid cells were set to simulate the EOL cell size which was measured in post irradiation examination.

The grids were tested with guide tube and chrome-coated fuel tube inserted into each guide tube cell and fuel rod cell to simulate the proper boundary conditions, respectively. 5 guide tubes were inserted into the guide tube cell and instrument tube cell. And 236 chrome-coated fuel tube were inserted into grid. The test equipment is universal testing machine with sensors (load cell, LVDT) and specimens is shown in Fig 1.

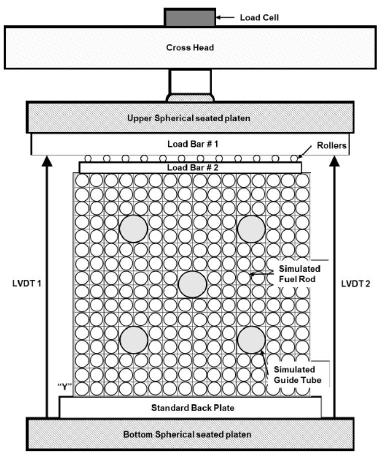

Fig. 1. Static Buckling Test Specimen and Equipment

2.3 Test Results

The results of the static buckling test with chrome-coated fuel tube and the buckling test with conventional zirconium fuel tube are shown in Table 3. The yield strength and stiffness of grids were derived from the test results.

The yield strength test results for the chrome-coated fuel tube were 17% greater at the BOL condition and 16% greater at the EOL condition compared to the conventional zirconium fuel tube. The chrome-coated layer is influenced the yield strength. As the spring force of the spacer grid increased at the BOL condition or gap between the fuel tube and spring/dimple decreased at the EOL condition due to chrome-coating layer, the yield strength of the spacer grid increased.

The stiffness test results for the chrome-coated fuel tube were 8% smaller at the BOL and 1% smaller at the EOL compared to the results for the conventional zirconium fuel tube. The grid stiffness with chrome-coated fuel tube at the BOL condition was lower than conventional fuel tube due to the lower elastic modulus and friction coefficient of the chrome-coated fuel tube. The chrome-coated fuel tube was not significantly affected on grid stiffness at the EOL condition because the simulated grid cell size after irradiation was larger than the diameter of the fuel tubes.

Table 3: Static Buckling Test Results (Ratio)

	Yield Strength		Stiffness	
	BOL	EOL	BOL	EOL
Conventional Zirconium Alloy	1	1	1	1
Cr-Coated HANA-6	1.17	1.16	0.92	0.99

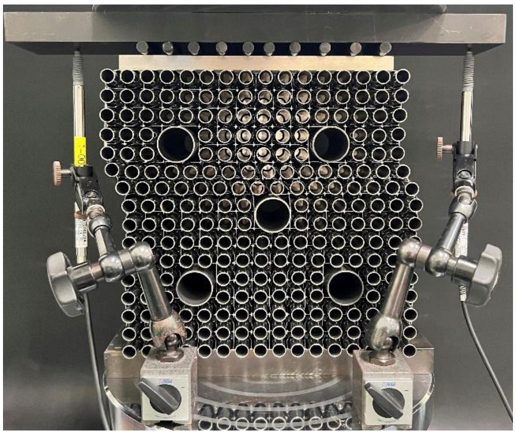

Fig. 2. Static Buckling Test Set-up

3. Conclusions

Static buckling tests were conducted on the spacer grids with conventional zirconium fuel tubes inserted and the spacer grids with chrome-coated fuel tubes inserted. The results showed that the yield strength of the spacer grid with chrome-coated fuel tubes was about 17% and 16% higher at the BOL and the EOL conditions, and the stiffness was 8% and 1% lower than conventional. The test results will be used to evaluate the mechanical design of nuclear fuel assemblies in the future.

Acknowledgements

This work was supported by the Innovative Small Modular Reactor Development Agency grant funded by the Korea Government (MOTIE) (No. RS-2023-00259032)

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