Optical Fiber Sensor Package Development for the SIT of Containment Structure

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1. Introduction

Various types of nuclear power plants are being constructed and operated in Korea, and in terms of regulatory control, a method of examining and evaluating the structural integrity of containment structure is being used.

Generally, after the construction has been completed, all containment structure go through a Structural Integrity Test(hereinafter SIT) in which the displacement occurring in a structure under greater internal pressure than it was designed for is measured and the result is comparatively assessed with the allowed criteria.

Most of the nuclear power plants in Korea are American type plants and their SIT uses the Invar-wire and Extensometer methods. These existing methods are expected to be used for the APR1400 plant currently being built unless some other reliable alternative technique is presented. This tendency can be observed in other countries, such as Japan, and there is thus insufficient effort to enhance the reliability of SIT through the implementation of the latest measurement technology.

Test using the Invar-wire and Extensometer methods contain problems such as inefficiencies in installation and inaccuracies in areas with micro-displacements, and regulatory agency and plants owner all recognize the need for improvements. Accordingly, improvements to SIT techniques through the introduction of the latest measurement technology can become an important factor in enhancing the competitiveness of Korean nuclear power technology, the construction ability of which has been acknowledged as world-class when Korea won the bid for UAE nuclear power plants.

2. Development and Verification

2.1 Development of Optical Sensor Package

Optical Fiber Sensor(hereinafter OFS) has a superior capacity in comparison to other measurement sensors in terms of their accuracy. Unlike regular structures such as a bridges, however, SIT require overhead installation rather than surface-mounted instrumentation. Also, noise occurs due to air current formation within the containment structure with its pressurized environment. Therefore, for the purpose of measuring short distance during SIT and obtaining exact measurements of micro-displacement occurrences such as equipment hatch, an OFS package was developed.

The main items to consider and acquire during the development of an OFS package for SIT are convenience of field installation, maintenance of OFS accuracy, and durability.

Because a FBG(Fiber Bragg Grating) type OFS needs to maintain a certain level of tensile force in order to detect strain as a sensor, it has the problem of having to set a fixed amount of quantity on the day of installation by tensioning it. To resolve the problem, an OFS tensioning control section was developed that utilizes a linear mode guide and tension bolts, which makes tensioning possible after a sensor has been installed on the field without the need for any special initial tensioning. To prevent sensor damage in parts of OFS that are exposed, a protective cover was applied, and in order to maintain a high level of accuracy, the work was carried out in such way as to minimize the strain loss due to friction from the protetive cover.

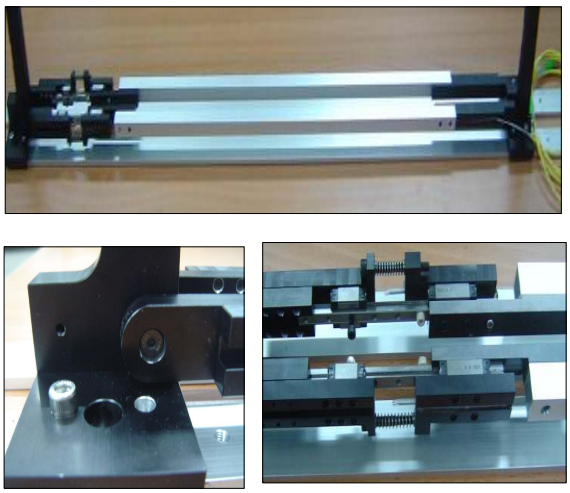

Fig.1. Optical Fiber Sensor Package

2.2 Property Value and Performance Testing

The FBG type optical fiber is a sensor that transforms the movement of waves reflected back from a light sent by an optic source to the sensor into strain. This kind of wave transformation occurs from two factors, external deformation and temperature changes, and they can be expressed as follows :

$$\frac{\Delta\lambda_B}{\lambda_B} = (1-\rho_\varepsilon)\Delta\varepsilon + \lambda_B(\alpha+\zeta)\Delta T$$

Accordingly, in order to calculate a reliable gage factor for the developed OFS package, there needs to be a process of carrying out temperature compensation by deriving the relationship between the waves and the strain from the displacement control test and calculating the accurate thermal expansion coefficient from the temperature change test.

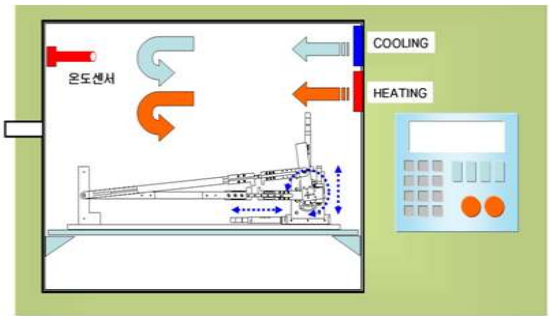

Fig.2. Temperature Change Test

When the OFS's wave value is converted to displacement, the conversion coefficient is applied during the tension in the pressurization stage and during the compression in the decompression stage in order to calculate the strain, and then the temperature measurement value is used in applying the temperature compensation algorithm to the SIT. The compensated strain value can be converted to displacement by multiplying it to the initial length measured during the installation, and this measured displacement is compared with the expected displacement from analyzing the relevant measurement spot during the SIT.

To verify the measurement capability and durability of OFS package under pressurized environment, a proof test was carried out using a 1/20 steel miniature containment structure.

To simulate SIT process, pressure maintenance during the pressurization stage was divided into 6 stages. However, because the purpose of this experiment was not to test the behavior of the miniature model but rather to evaluate the applicability and durability of the developed OFS package, the pressurization speed was set to be as fast as possible in order to shorten the time, and the pressure stabilization period for each stage was set at 15 minutes.

- Peak pressure : 65.6psig(4.61kgf/㎠)
- Pressure step : 10, 25, 35, 45, 57, 65.6psig
- Pressure stabilization time : 15minute
- Measuring interval : 5minute

Fig.3. Steel Miniature Containment Structure

The results of the test showed that the developed OFS package not only revealed normal displacement behavior characteristics following pressurization and decompression but also sustained no physical damage, thus verifying that it maintained measurement applicability and needed durability.

3. Conclusions

The SIT of a containment structure is a process that must be carried out to substantiate the structural soundness of nuclear power plants after their construction. With the OFS package it was developed in order to prevent noise caused by air current formation inside the containment structure in a pressurization environment, to achieve convenience in field installation and durability. The results in this paper will not only contribute to solving problems that exist in the SIT techniques but also be used as part of the effort to obtain technical competitiveness in structures in order to dominate the overseas nuclear power plant market, which is receiving attention as a new national growth engine.

REFERENCES

[1] ASME Boiler & Pressure Vessel Code Ⅲ Div. 2, "Code for Concrete Containments, CC-6000 Structural Integrity Test of Concrete Containment", 2007
[2] Micron Optics Inc. "Sensing Instrumentation & Software, ENLIGHT Manual", 2007