Simultaneous Measurement of Temperature and Humidity using OTDR Based on Fiber-Optic Sensor System

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1. Introduction

In this study, we developed a fiber-optic sensor system (FOSS) which can measure real-time temperature and humidity simultaneously. It is for monitoring and detecting the leak before break (LBB) easily at a coolant pipe of the nuclear power plant. By measuring the temperature and humidity simultaneously, FOSS can enhance the accuracy and minimize the error of detecting the LBB.

2. Methods and Results

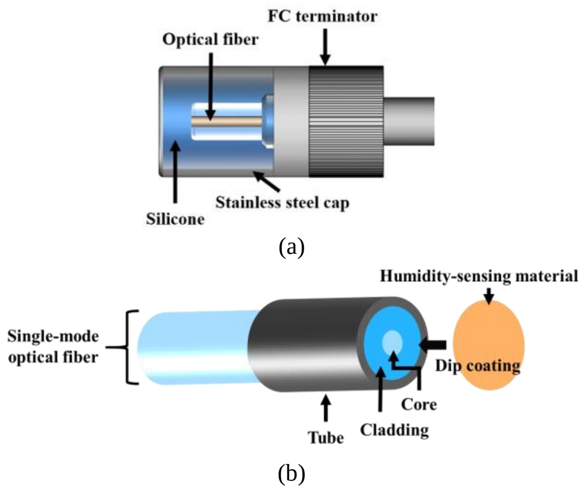

Fig. 1. Internal structure of the sensing probe; (a) FOTS, (b) FOHS.

The FOSS consist of a fiber-optic temperature sensor (FOTS), a fiber-optic humidity sensor (FOHS), a fiber-optic coupler, a transmitting optical fiber and an optical time domain reflectometer (OTDR). Fig. 1 shows the structure of the sensing probe of FOTS and FOHS. The sensing probe of FOTS is composed of a temperature sensing material, a FC terminator, a stainless steel cap, and a single-mode optical fiber. The sensing probe of FOHS is composed of humidity sensing material, a FC terminator, and a single-mode optical fiber. Also, the temperature sensing material and the humidity sensing material are comprised of the silicone oil and HEC/PVDF, respectively. Fig. 2 shows the experimental setup for evaluating FOTS and FOHS the at one time. In the experimental setup, we used optical instrument called OTDR and measured optical power of the reflected light signal by Fresnel reflection. The Fresnel reflection is generated on the interface between the sensing material and the core of a single mode fiber-optic in the end of sensing probes. It is changed according to varying the reflective indices of the sensing materials by the environment (temperature and RH). The sensing probe of FOTS is placed inside of the water with a thermal variation from 10 to 70℃ and the sensing probe of FOHS is placed inside of the humidity chamber with a humidity variation from 50 to 95%. Also, the real value of temperature and RH can be detected using the thermocouple and a reference RH meter.

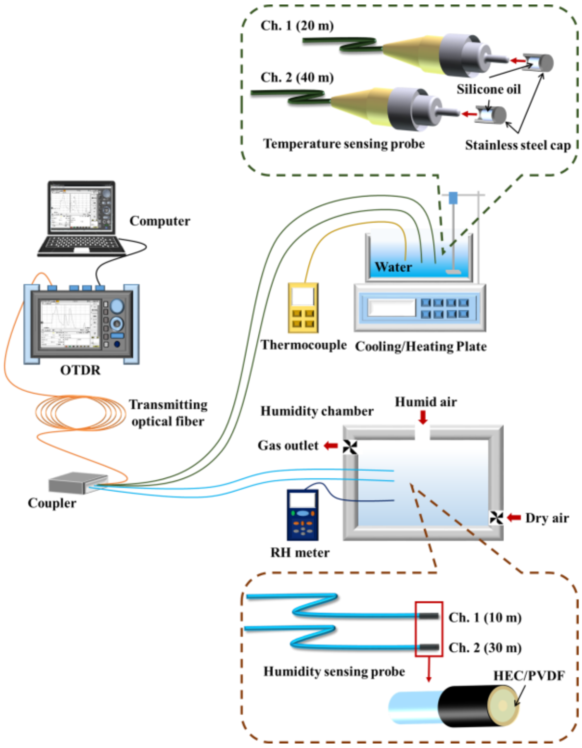

Fig. 2. Experimental setup for evaluating the distributed FOSS.

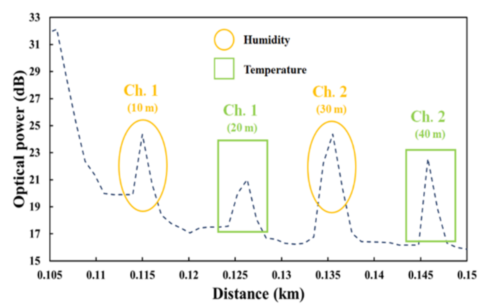

Fig. 3. The output signals of the two FOTS channels and the two FOHS channels from OTDR

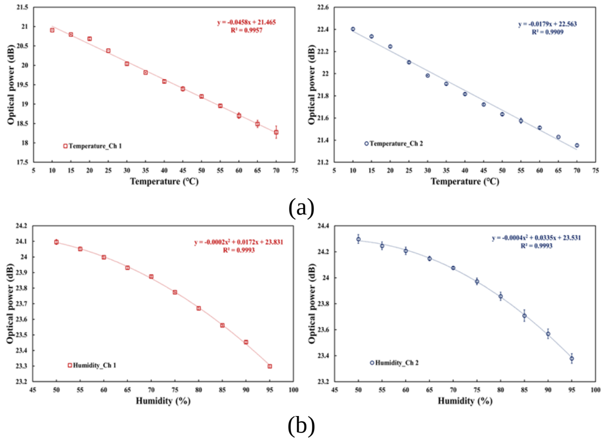

Fig. 4. (a) Relationship between the temperature of water and the optical power of two FOTS channels, (b) Relationship between the RH and the optical power of two FOHS channels

Fig. 3 shows the output signals of the FOTS and FOHS which have two channels respectively, through the OTDR. The output signal of each sensor is divided by the length difference of the single mode fiber-optic.

Fig. 4 shows the relationship between the variable of temperature and humidity and the optical power of the sensors. Each channel of FOTS and FOHS has same trend of output signal.

As the result of the experiment, according to the temperature and the RH change, the optical power of the FOTS and FOHS decreased linearly. In the FOSS, a change in the optical signal of the FOTS has no effect on the FOHS. Therefore, they are individually changed and independently measured through the OTDR. With this result, it is possible to simultaneously confirm measuring the temperature and the RH and determining the location information of the installed probes by using each of the probes in the FOSS.

3. Conclusions

In this study, a novel FOSS has been proposed using an economical OTDR and sensing materials. Through the experimental results, we confirmed that the proposed FOSS for the temperature and the RH measurement works well. Especially, FOSS has high sensitivity and good linear response, when the FOTS and the FOHS are measured within the measurement range of 5 to 70℃ and 50 to 95% respectively.

It is expected that the OTDR based FOSS could be efficiently used in real-time measurement for temperature and RH sensing. Further studies are planned to develop the distributed multi-channel FOSS using an optical switch for leakage detection and monitoring in nuclear power plants.

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