Transactions of the Korean Nuclear Society Virtual Spring Meeting
July 9-10, 2020

Proof of Concept Test of FBG (Fiber Bragg Grating)-based Pressure Transmitter

Byeong-Yeon Kim*, Hyungmo Kim, Youngil Cho, and Jewhan Lee
Korea Atomic Energy Research Institute, Daedeok-daero 989-111, Yuseong-gu, 34057, Republic of Korea.
**Corresponding author:byeongyeon@kaeri.re.kr*

1. Introduction

In recent years, FBG (Fiber Bragg Grating) has attracted a lot of research interest due to its potential benefit to sensor applications [1-3]. A FBG-based pressure transmitter over a wide range of temperature and low pressure range is being developed at KAERI (Korea Atomic Research Institute). In the sensing scheme, a FBG is strained by pressure through a diaphragm, and it produces shift of the Bragg wavelength. Thus, pressure can be measured by monitoring shift of the wavelength. Compared with conventional pressure sensors, the FBG-based sensor has the advantages of high resolution, easy to be cascade, and having no effect on electromagnetic field. The developed pressure transmitter has potential to be applied to various liquid metal systems with high temperature and low pressure range since there is few pressure transmitter for those systems.

In this paper, we have provided proof of concept of a prototype of FBG-based pressure transmitter.

2. Proof of Concept Test of FBG-based Pressure Transmitter

2.1 Overview of a Prototype of FBG-based Pressure Transmitter

The prototype of FBG-based pressure transmitter is shown in Fig. 1. The FBG-based pressure transmitter is composed of two FBG elements for discrimination between pressure and temperature. The first element is for measuring wavelength caused by system pressure from diaphragm deformation and that caused by temperature of the FBG element. The second element is only for measuring wavelength caused by temperature of the FBG element. Thus, pressure without the effect of temperature can be calculated from the wavelength measurements of two FBG elements. The specification of the prototype of pressure transmitter is shown in Table I.

Fig. 1. The prototype of FBG-based pressure transmitter

Table I: The Specification of the developed pressure transmitter

	Specification
Design Pressure Range	Max. 300 kPa
Design Temperature	Max. 550 ℃
Diaphragm Material	SS316
Wavelength Range	1510~1590nm

2.2 Setup of Proof of Concept Test

Test equipment for the pressure transmitter is shown in Fig. 2. The test equipment is composed of a chamber, an Ar gas cylinder, a ceramic mold type heater, a heater controller, thermocouples, a reference pressure transmitter, an interrogator, and DAS (Data Acquisition System). The FBG-based pressure transmitter is installed on the test equipment as shown in Fig. 2. The FBG-based pressure transmitter as well as the reference pressure transmitter can measure pressure of Ar gas in the chamber. The reference pressure transmitter is not affected by the thermal expansion of Ar gas because it is installed through sufficiently long impulse line from the chamber. The temperature of Ar gas is controlled by the ceramic mold type heater, thermocouple, and the heater controller. The proof of concept test has been carried out for various pressure and temperature conditions given by the test matrix as shown in Table II.

We have carried out proof of concept test for six pressure conditions (0 kPa, 30 kPa, 60 kPa, 90 kPa, 120 kPa, and 150 kPa) and three temperature conditions (200℃, 250℃, 300℃) since we are interested in pressure measurement in low pressure and high temperature condition. Fig. 3 describes test procedure for the developed pressure transmitter.

Fig. 2. Test equipment for the developed pressure transmitter

Table II: Test matrix

Temperature (℃) \ Pressure(kPa)	0	30	60	90	120	150
200	O	O	O	O	O	O
250	O	O	O	O	O	O
300	O	O	O	O	O	O

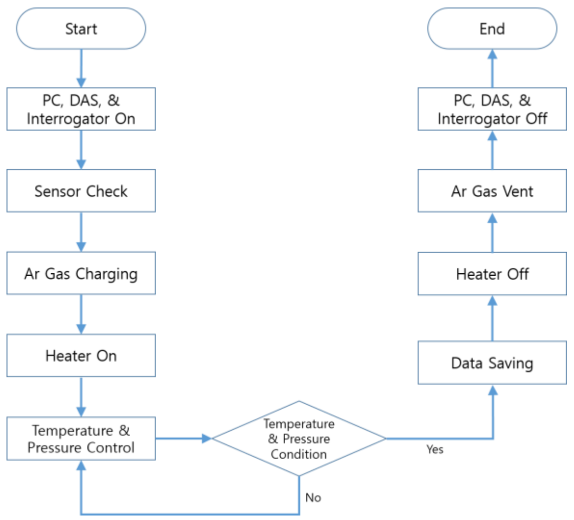

Fig. 3. Test procedure

2.3 Proof of Concept Test Results

Fig. 4 shows the wavelength of FBG element for system pressure measurement at different three temperature conditions and six pressure conditions. As shown in Fig. 4, the wavelength of FBG element increases as the temperature increases at the same pressure condition. The wavelength shown in Fig. 4 is required to be separated by temperature induced wavelength shift and pressure induced wavelength shift since the wavelength is affected by pressure as well as temperature. Fig. 5 shows the wavelength of FBG element for temperature compensation at each temperature. The wavelength of FBG element for system pressure measurement can be compensated by that of FBG element for temperature compensation. The performance of the developed pressure transmitter with temperature compensation versus reference transmitter based on percentage of full scale at different three temperature conditions and six pressure conditions is shown in Fig. 6. As shown in the Fig. 6, the full scale accuracy error is less than 2.1664%. We believe that the concept of the developed pressure transmitter has been verified through the proof of concept test and performance can be improved by optimization in the next step based on the results.

3. Conclusions

Proof of concept for a prototype of FBG-based

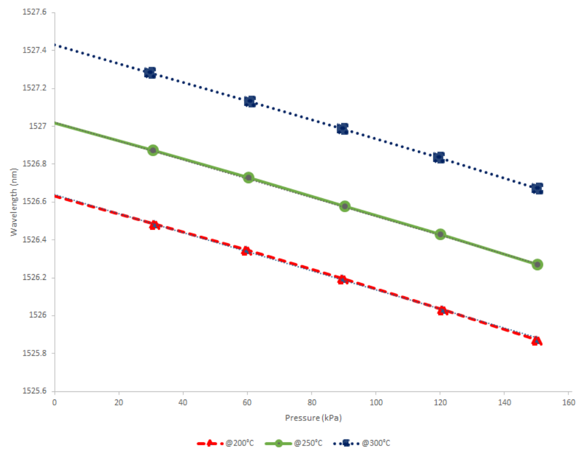

Fig. 4. Wavelength of FBG for system pressure measurement including temperature induced wavelength shift at each temperature

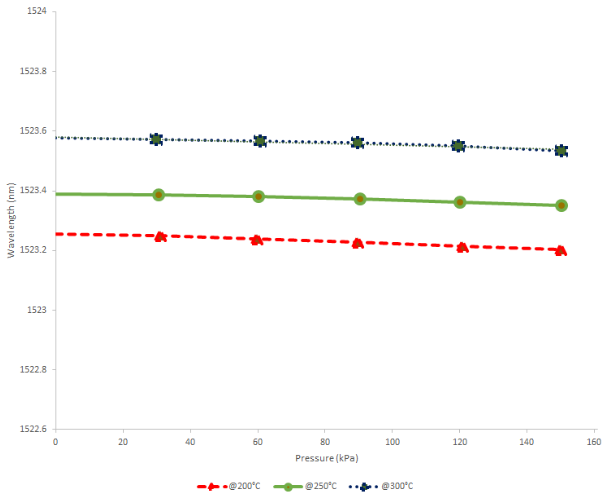

Fig. 5. Wavelength of FBG for temperature compensation at each temperature without pressure induced wavelength shift

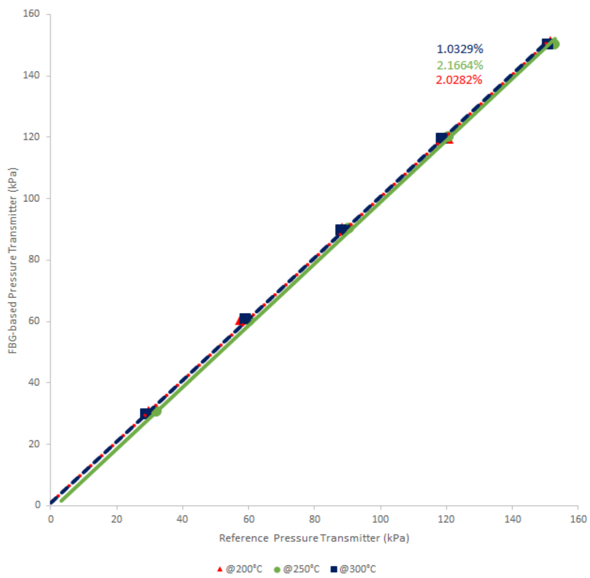

Fig. 6. The percentage of full scale accuracy of the developed pressure transmitter with temperature compensation versus the reference pressure transmitter

pressure transmitter has been provided in this paper. We have carried out test of the developed pressure transmitter for six pressure conditions (0 kPa, 30 kPa, 60 kPa, 90 kPa, 120 kPa, and 150 kPa) and three temperature conditions (200℃, 250℃, and 300℃). The full scale accuracy error of the developed pressure transmitter is less than 2.1664% throughout 200℃~300℃ with the temperature compensation. For the high temperature, thermal expansion of internal structure of pressure transmitter can affect the accuracy over a wide range of temperature. Thus, for reducing the effect of thermal expansion, changing material with low thermal expansion coefficient for the internal structure of pressure transmitter could be considered. The results can be used for performance improvement of the developed pressure transmitter for further works.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). (No. 2012M2A8A2025635)

REFERENCES

[1] Song, M., et al., “Simultaneous measurement of temperature and strain using two fiber Bragg gratings embedded in a glass tube,” Optical Fiber Technology, vol. 3, no. 2, 1997.
[2] James, S.W., et al., “Simultaneous independent temperature and strain measurement using in-fibre Bragg grating sensors,” Electronics Letters, vol. 32, no. 12, 1996.
[3] Xu, M.G., et al., “Discrimination between strain and temperature effects using dual-wavelength fibre grating sensors,” Electronics Letters, vol. 30, no. 13, 1994.