International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

Speed Sensor Study Using A Single Fiber Bragg Grating (FBG)

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Abstract: ***Optical Fiber Sensors (OFS) based on Fiber Bragg Grating (FBG) technology possess several advantages such as sensitivity, reliability, low intrusively, galvanic insulation, as well as the ability to provide quasi-distributed remote measurements. FBGs are extensively employed in optical sensing and can compete favourably with traditional electrical strain gauges. In this research, speed sensor using a single Fiber Bragg Grating has been studied. The study was conducted using an Optical Spectrum Analyzer (OSA) and a 1300nm Super Luminescent Diode (SLD). The experiment resulted in the bending of the FBG. In this experiment, the FBG was located inside a wind tunnel. An increasing bending of the FBG was noticed as the speed and pressure in the tunnel increased from 7.22 to 27.25 m/s and 31.90 to 450.80 Pa respectively. The Bragg wavelength shift also increased with speed and pressure. The measured sensitivities were 0.0058nm/ms^{-1} for speed and $0.0463\ ms^{-1}/Pa$ for wind pressure. The sensitivity measurements are very important especially when FBG is to be applied as a sensing system. As such, the FBG in question can be used as a strain sensor, wind pressure sensor and wind speed sensor.***

Keywords: Fiber Bragg Grating FBG, Wind Tunnel, Optical Spectrum Analyzer OSA, Super Luminescent Diode SLD, Sensing

1. Introduction

Fiber Bragg Gratings (FBGs) have completely revolutionized the world of sensing and communications. They can be described as one the most important inventions of the last decade owing to their ability to be readily deployed in harsh environments for the prediction of natural disasters such as earthquakes. Fiber Bragg Grating (FBG) sensors have been deployed for years in extremely harsh environment applications as an alternative to traditional electrical and mechanical sensors. Generally, FBG sensors give higher accuracy, longer stability, smaller size; immunity to electromagnetic interference (EMI) and the ability to measure ultra-high speed events.FBGs have been employed in sensing systems for measuring physical quantities such as temperature [1], strain [2] and pressure [3].

Fiber Bragg grating (FBG) is a short length of optical fiber that filters out a particular wavelength. It is a periodic perturbation of the refractive index along the fiber length which is formed by the exposure of the core to create an intense optical interference pattern. These perturbations are affected by UV radiation interference pattern exposed to the core of this fiber [4, 5].

In this study, FBG was used for strain sensing purpose due to bending. When the FBG is strained by windspeed, there is a shift in Bragg wavelength due to the strain produced. This study investigated the effect of wind speed on the transmission characteristics of a FBG with particular emphasis on the Bragg wavelength shift, $\Delta\lambda_B$.

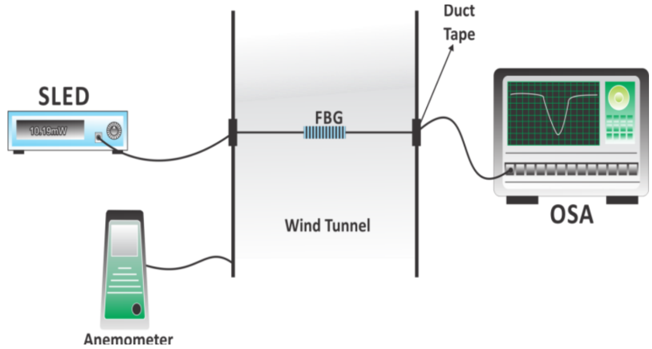

Figure 1: Schematic diagram of the wind tunnel set up when the axial fan is off

With the fan turned on, the speed of the wind impinging the FBG was varied by controlling the number of revolutions the fan makes in one minute. The impact of the wind on the FBG caused it to be bent. The wind speed and the wind pressure the FBG was subjected to were monitored using an anemometer and the values were duly recorded. The wind speed varied from 7.22 m/s to 27.25 m/s while the wind pressure in the tunnel was from 31.90 to 450.80 Pa.

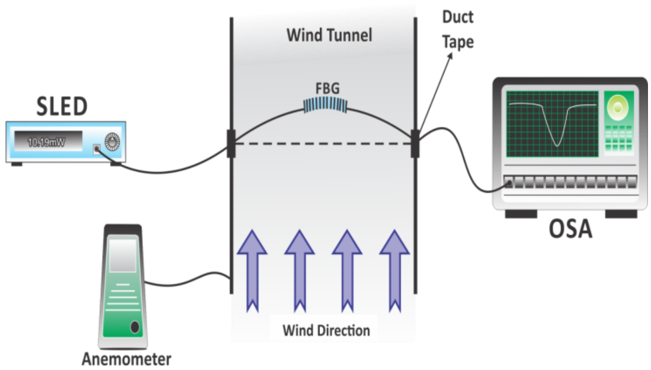

Figure 2: Schematic diagram of the wind tunnel set up when the axial fan is on.

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2. Results and Discussion

The Bragg wavelength, λ_B and the Bragg wavelength shift, $\Delta\lambda_B$ were obtained using an Optical Spectrum Analyser (OSA) after the Fiber Bragg Grating (FBGs) was strained by bending in the wind tunnel due to the action of uniform flow of wind in the tunnel.

It is also evident from the transmission display on the OSA that the values of the Bragg wavelength, λ_B and hence the Bragg wavelength shift, $\Delta\lambda_B$are gradually increased by increasing the wind speed and pressure in the wind tunnel. The initial spectral shape was not modified as the speed increased because of the laminar flow within the tunnel [6].

Table 1: Analysis of Bragg Wavelength shift due to variation of speed when the FBG with a central wavelength of 1280.334 nm is placed in the wind tunnel

Speed(m/s)	*Wavelength, λ (nm)*	*Shift, Δλ (nm)*
7.22	1280.336	0.000
9.91	1280.344	0.008
13.18	1280.360	0.024
15.7	1280.376	0.040
17.49	1280.384	0.048
19.71	1280.400	0.064
21.91	1280.416	0.080
24.56	1280.432	0.096
27.25	1280.448	0.112

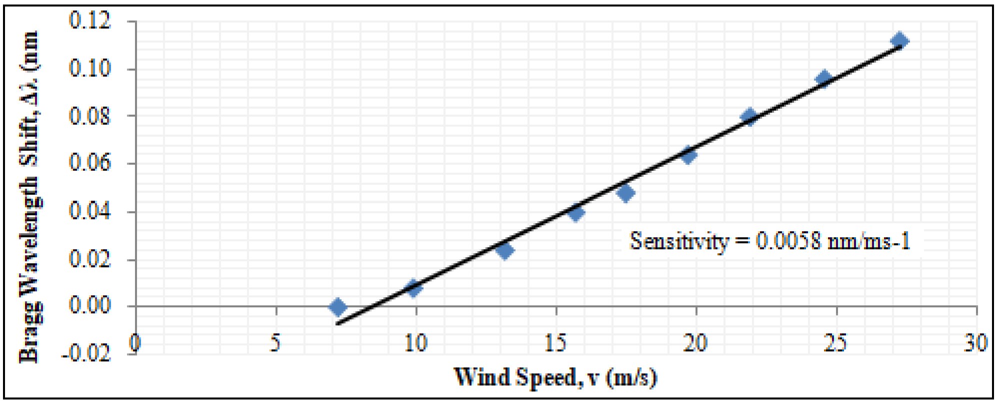

Figure 3: Wind speed against Bragg wavelength shift in the wind tunnel

From the data recorded from the wind tunnel experiment, the plot of Bragg wavelength shift, $\Delta\lambda_B$ against wind speed gave a linear response and a sensitivity of 0.0058 nm/ms^{-1} as depicted in Figure 3. Figure 3 shows the results obtained under variable speed conditions from 7.22 to 27.25 m/s as a function of the Bragg wavelength shift from 0 to 0.112 nm.

Table 2: Analysis of wind speed and wind pressure obtained from the wind tunnel for 1280.334 nm FBG

Wind Speed (m/s)	Wind Pressure (Pa)
7.22	31.9
9.91	60.5
13.18	106
15.70	150.3
17.49	188
19.71	238.5
21.91	294.4
24.56	370.6
27.25	450.8

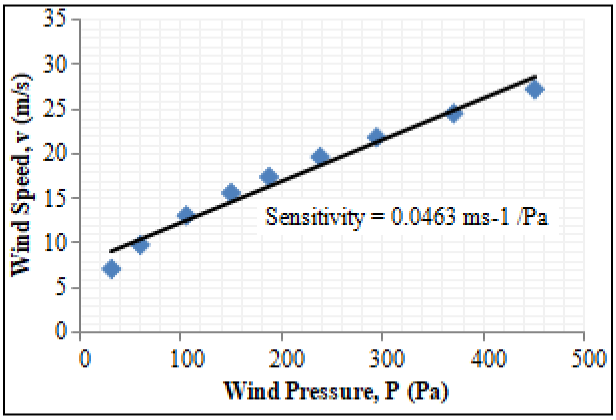

Figure 4: Wind speed against Wind Pressure in the wind tunnel

To analyse the FBG further, wind speed was plotted against the wind pressure data obtained from Table 2. Figure 4shows a plot of wind speed against wind pressure in the tunnel. A linear relationship exists between the wind speed and the wind pressure. The wind speed was varied from 7.22 to 27.55 m/s while the pressure ranged from 31.9 to 450 Pa.

To test the consistency of the results obtained from the first FBG. A second FBG with a central wavelength 1288.376 nm was placed in the wind tunnel and subjected to the same conditions as the first.

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Table 3: Analysis of Bragg Wavelength shift due to variation of speed when the FBG with a central wavelength of 1288.376 nm is placed in the wind tunnel

Speed(m/s)	Wavelength, λ (nm)	Shift, Δλ (nm)
7.20	1288.376	0.000
9.63	1288.385	0.009
12.66	1288.401	0.025
14.83	1288.417	0.041
17.33	1288.426	0.050
20.30	1288.442	0.066
21.95	1288.450	0.074
24.90	1288.475	0.099
27.30	1288.491	0.115

The results obtained from the experiment with the second FBG were plotted. A linear response is obtained when Bragg wavelength shift is plotted against wind speed. Wind speed values from 7.20 to 27.30 m/s were plotted against Bragg wavelength shift values of 0 to 0.115 nm and a sensitivity of 0.0057 nm/ms^{-1} was obtained as shown in Figure 5.

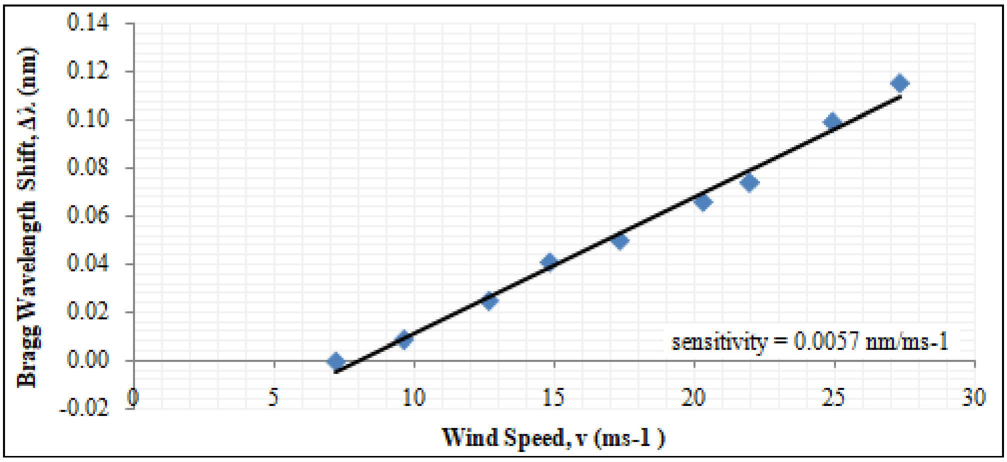

Figure 5: Bragg wavelength shift against wind speed for 1288.376 nm FBG in a wind tunnel

Table 4: Analysis of wind speed and wind pressure obtained from the wind tunnel for 1288.376 nm FBG

Wind Speed (m/s)	Wind Pressure (Pa)
7.20	31.60
9.63	56.60
12.66	97.90
14.83	134.30
17.33	183.50
20.30	251.60
21.95	294.80
24.90	378.50
27.30	455.10

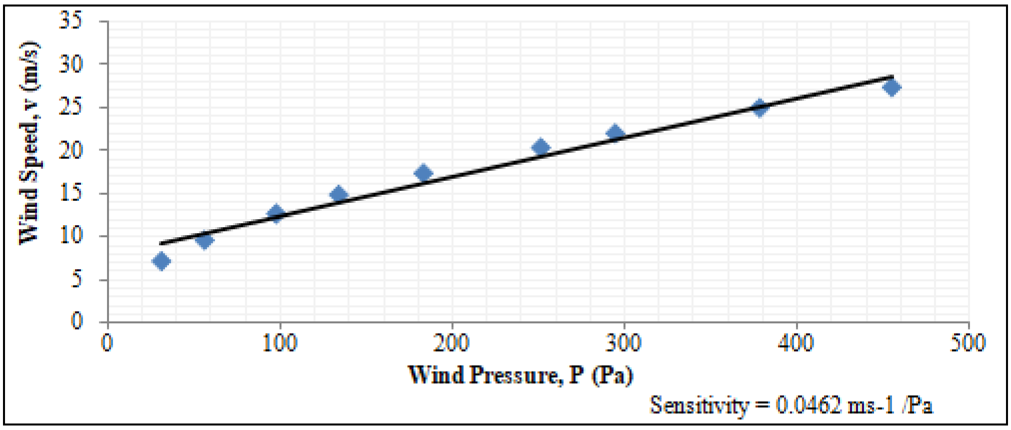

Figure 6: Wind speed against wind pressure for FBG with Central wavelength of 1288.376 nm in a wind tunnel

Wind speed in the range 7.20 to 27.30 m/s was plotted against wind pressure ranging from 31.60 to 455.10 Pa as obtained in Table 4. A linear response with a measured sensitivity of 0.0462 ms^{-1}/Pa is obtained as shown in Figure 6.

3. Discussions

The effect of wind on the FBG has been analysed. The Bragg wavelength shift with displacement and wind speed are clearly observed. This is due to the perturbations of the gratings resulting in the transmission spectra.

In the wind tunnel experiment for FBG with a central wavelength of 1280.336nm, Figures 3 and 4 showed linear responses when the Bragg wavelength shift was plotted against wind speed and when wind speed was plotted against pressure. The measured sensitivities are 0.0058 nm/ms^{-1} and 0.0463ms^{-1}/Pa respectively.

The FBG with a central wavelength of 1288.376nm as depicted in Figures 5 and 6 gave linear responses when the Bragg wavelength shift was plotted against wind speed and when wind speed was plotted against pressure. The measured sensitivities are 0.0057 nm/ms^{-1} and 0.0462 ms^{-1}/Pa. This result showed consistency between the first and second FBG.

The sensitivities obtained from experiments can be used to determine the performance of the FBG when used in wind speed sensing systems.

4. Conclusion

A linear response was also observed with the wind tunnel experiments. Both FBGs used in the tunnel at different times but subjected to the same conditions gave similar results despite a difference in their centre wavelengths. As a result of its sensitivity FBGs can be adapted to measure wind speed and wind pressure.

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