Analysis of bend loss in loaded fiber coil for a circular and an elliptical shape

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Abstract

Bending in the optical fiber can result in a loss of optical fiber. Bending causes the output light intensity smaller than the intensity of the light source. Bending can be utilized to a sensor based on optical fiber. This paper presents to know the correlation between the optical fiber sensor utilizing bending effect with rubber coil to a circular and an elliptical shape.

The principle of this sensor is a detecting change in the output voltage through an optical fiber. The output voltage then converted to transmittance with the program of a computer. The optical fiber is divided into two arms, that is one reference arm and one modulate arm. Fiber bending sensor was made by cooling optical fiber in modulating arm. The displacement loaded to the optical fiber coil in a rubber thread, so that occurs of bending. Rubber threaded used to have a 1.0 cm diameter for the circular shape, and 1.1 cm mayor axis and 0.9 cm minor axis for the elliptical shape. Tests are taken from variations in a number of turns, that are 1, 2, 3, and 4 turns and displacement load from 0.0–10.0 mm.

The results can be concluded that the loss is greater with the more number of turns. The larger of displacement load has also resulted in the greater loss. The ratio of loss generated to both of the rubber shapes is visible. The circular shape shows that the loss is a very small firstly. But, after the cross section coil turned into an elliptical shape with a minor axis, the loss increased significantly. While for the elliptical shape shows that the loss increased significantly from the first displacement loaded.

1. Introduction

The function of optical fiber is a light transmission line from one to another place. The optical fiber has been utilized since 1970 as a communication system. Many researchers have been used optical fiber to expanding research. One of this is an optical fiber sensor. The optical fiber has many advantages, such as a very sensitive, hold up with electromagnetic interference and radiation, and low noise [3].

Optical fiber sensor categorized by modulation principle, that are optical fiber sensor based on shift intensity, shift phase, and shift wavelength [2]. Optical fiber sensor based on shift intensity utilize occurrence attenuation signal output from the optical fiber. Attenuation carried out by bending on the optical fiber [1]. Bending is a mechanical disorder that causes redistribution of light power in an optical fiber. Bending generates transmission loss thus providing sensor sensitivity characteristics. Bending are classified into macro bending and micro bending. Macro bending is a bending of the
optical fiber with a radius of curvature is greater than a radius of the optical fiber. Micro bending is a microscopic bending from the core of an optical fiber. This is due to the difference in thermal contraction between core and cladding [4].

2. Experiment
Figure 1 is the scheme of used in this experiment. Light source comes from light emitting Diode (LED, $\lambda=\pm635$ nm). Light has a split to 2 arms. One arm is coming in to optical fiber within modulation; it’s called reference arm. And the other arm is coming in to optical fiber modulated; it’s called modulation arm [1]. Modulation arm created by wrapping the optical fiber in the rubber cylinder coil. Fiber coil created from a rubber silicone RTV 588. The diameter of fiber coil is 1.00 cm for a circular shape, and 0.9 cm of the minor axis and 1.1 cm of the major axis for an elliptical shape. The optical fiber used in this experiment is a polymer optical fiber (POF). Light is coming out from the both of arms detected by a light detector. A light detector connected with the microcontroller arduino uno. Arduino uno is a microcontroller has function of conversion data analog to digital or otherwise. Arduino uno connected with a computer to display data output using software Labview 2012.

![Figure 1. Experiment scheme of optical fiber sensor based on bend loss](image)

First, taking data has carried out with a circular rubber coil shape. A light output intensity from the reference arm ($I_{ref}$) has set to as big as the modulation arm ($I_{mod}$), so obtained the transmittance value equal to 1 ($T=1$). As for the transmittance formula can be seen equation (1).

$$T = \frac{I_{mod}}{I_{ref}}$$  \hspace{1cm} (1)

After the value $T=1$, then the modulation arm gave displacement load from 0.0–10.0 mm. Displacement load will change the cross section coil from circular shape to elliptical shape with minor axis ($x=y$–axis). Loss calculated from the transmittance data with the equation (2). As for the correlation of transmittance with loss is:

$$Loss\,(dB) = 10^{\frac{1}{10}\log\left(\frac{1}{T}\right)}$$  \hspace{1cm} (2)
$$Loss\,(dB) = 10^{\frac{1}{10}\log\left(\frac{I_{ref}}{I_{mod}}\right)}$$

3. Results and Discussion
Data obtained from this experiment is a reference intensity ($I_{ref}$), modulation intensity ($I_{mod}$), and displacement load ($d$). Data used to calculation transmittance and loss with equation (1) and (2).
Figure 2. Bend loss from the circular shape

Figure 2 shows that loss is greater with the larger displacement load. The more number of turns has also resulted in the greater loss. However, a loss is very small when the displacement load at 0.0–1.0 mm. This shows that in the circular shape coil less sensitivity on very small displacement load. Rubber coil requires displacement load along d prior to sensitivity.

Figure 3. Coil cross section change. (a) No external force. (b) External force

This experiment performed with the variation of turns from 1–4 turns, and variation of displacement load from 0.0–10.0 mm. Displacement load M obtained with emphasis. Emphasis carried out by using the micrometer screw. Figure 3 shows that the rubber coil shape. Figure 3a is no external force applied (F=0), rubber coil is a circular shape. Figure 3b is an external force applied (F≠0), rubber coil is changed to an elliptical shape. Both have the same value of perimeter K [5], Equation of an elliptical shape perimeter is

\[ K_{el} = 2\pi \left( \frac{l^2+m^2}{2} \right)^{1/2} \]  \hspace{1cm} (3)

where \( l \) is a radius of the major axis, \( m \) is a radius of the minor axis. The perimeter of an elliptical shape as big as the circular shape \( K=2\pi r \), so can write

\[ 2\pi r = 2\pi \left( \frac{l^2+m^2}{2} \right)^{1/2} \]  \hspace{1cm} (4)
So,

\[ l = (2r^2 - m^2)^{1/2} \]  

(5)

the radius of the minor axis is \( m = r - d/2 \) (\( d \) is a displacement), so equation (5) can write

\[ l = \left( r^2 + rd - \frac{d^2}{4} \right)^{1/2} \]  

(6)

From the equation 5, \( m = r - d/2 \) and \( d = 1 \, \text{mm} \), accordingly obtained elliptical shape with \( l = 0.9 \, \text{cm} \), and \( m = 1.1 \, \text{cm} \).

![Elliptical Shape](image)

**Figure 4.** Bend loss from the elliptical shape

Figure 4 shows that loss is greater significantly from the displacement load 0.0 mm. This shows that rubber coil with the elliptical shape has the higher sensitivity from the circular shape.

4. Conclusions

The experiment to analysis bend loss created by wrapping the optical fiber in the rubber coil a circular and an elliptical shape. The diameter of rubber coil is 1.00 cm for a circular shape, and 0.9 cm of the minor axis and 1.1 cm of the major axis for an elliptical shape. The loss is greater with the more number of turns. The larger of displacement load has also resulted in the greater loss. The circular rubber coil shapes less sensitivity on very small displacement load. While the elliptical rubber coil shape sensitively. The rubber coil with the elliptical shape has the higher sensitivity from the circular shape.

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