Implementation optical fiber sensor using macro bending method for flood sensor

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Abstract. An experimental study has been conducted to analyze the losses due to the fiber optic macro bending to be applied to the flood sensor. Optical fiber macro bending occurs when an optical fiber is bent with a radius wider than the radius of the optical fiber. Data retrieval is gathered by measuring the change in the value of the light intensity due to the presence of symptoms bend (macro bending) on optical fibers that cause the symptoms of losses optical fiber application that read in Arduino IDE. Optical fibers used are plastic optical fiber diameter of 0.3 mm and light sources are red LED (610 < λ < 760 nm). The silicone rubber used is 3.2 cm in diameter with 5 turns. Results of the research showed that the greater the bending is given, the greater the value of losses in optical fiber will be, the trend graphs show the value of the sensitivity of the sensor for $R^2 = 0.8765$, so the inferred design sensor devices made have the potential to be applied as flood sensors.

1. Introduction
Floods are a hydrometeorological hazard that can kill many people and cause property losses, so mitigation efforts are needed to minimize the disaster. Three main factors cause flooding, namely reduced tree cover, extreme weather, and topographical conditions of watersheds. One of the solutions to minimize hydrometeorological disasters is to conduct an early warning system. Accurate and real-time rainfall information is needed in various fields such as floods, landslides, and droughts in research related to the hydrological cycle [1, 2]. Therefore, to provide early warning of flood disasters required a tool that can detect moving up and down the water level. The sensors are made to detect moving up and down the water level by using optical fiber macro bending. Compared to other flood sensors, optical fiber has its advantages, namely corrosion resistance and high sensitivity. This proves that optical fiber is very good and suitable for the sensor.

Optical fibers were first envisioned as optical elements in the early 1960s [3]. It was developed in the early 1970s and is rapidly replacing traditional copper cable for transmitting information over hundreds to thousands of miles. Optical fiber has been widely used as a communication and sensor system because of its high performance including anti-interference, corrosion resistance, high sensitivity, remote sensing, and low cost [4-7]. The basic fiber optic communication system consists of three components an optical transmitter, optical fiber wire, and optical receiver. Optical fiber works by limiting and directing [8, 9] light waves in long glass strands by the principle of total internal reflection. Optical fiber is a cylindrical dielectric waveguide made of a glass cylinder center with one refractive index, surrounded by an annulus with a small index [10]. Most practical telecommunication-grade
single-mode fibers are classified as weakly guiding because the difference in the refractive index of the core and the cladding is very small, less than 0.01 [11, 12]. When the light propagating in the optical fiber, various factors can cause signal energy to decrease. The method to calculate the bending loss in an ordinary single-mode fiber is by macro bending method and calculating its power loss coefficient, for example by using a classical formula introduced by Marcuse [13]. To utilize optical fiber in the making of the flood sensor, this research was conducted.

2. Methods
The research aims to apply optical fiber for flood sensors using the macro bending method. The starting preparation of this research is to make sure the sensor works when the optical fiber is subjected to water pressure in Figure 1, then determining the relation of the radius of curvature with the resulting loss value. The system used is divided into three parts shown in Figure 1, which are light sources, detectors, and data acquisition tools. The light source used is a red LED with 2 photodiode detectors. The LED will inject light into the optical fiber so it will be detected by the photodiode. The optical fiber used has a diameter of 0.3 mm with two photodiodes as references and captures the final data. For data acquisition using the Arduino IDE to process data received by the photodiode (detector).

![Figure 1. The research equipment set-up scheme](image)

The data was collected by varying macro bending diameter and the number of fiber optic turns. The initial measurement of optical fiber was carried out with the initial diameter and turns equal 3.2 cm and 5 turns, respectively. An example of the set up of measurements for the calculation of macro bending losses is shown in Figure 2.

![Figure 2. Set up measurements for macro bending loss calculations](image)
3. Results and Discussion

The working principle of optical fiber-based sensors is to take advantage of light losses that cannot be transmitted due to macro bending. By compressing the optical fiber, there will be light losses, since the smaller diameter of the optical fiber, so bigger loss produced. This is due to the supporting factors, the optical fiber which is wrapped around the rubber becomes elliptical so that some rays that enter the optical fiber can be transmitted (transmitted) and some cannot be transmitted (loss). This is the basic principle of light guidance through optical fiber.

Figure 3. A typical optical fiber waveguide consists of thin cylindrical [9].

Modeling of bend losses for a realistic single-mode fiber with multiple cladding layers has been presented by Zendehnam et al. [14] and Wang et al. [15]. The transmitted light has an angle that is greater than the critical angle so that perfect reflection occurs. Figure 4. shows the measurements of the fiber optic wire with a diameter equal to 3.2 cm – 2 cm by compression treatment.

Figure 4. Graph of the measurements of the fiber optic wire with a diameter equal to 3.2 cm – 2 cm by compression treatment.

Figure 3 shows the results of the optical fiber compression treatment of 3.2 cm - 2 cm with an $R^2$ value of 0.8765. The more $R^2$ approaches the value 1, proving that the sensor is more sensitive. As a result of this emphasis, the optical fiber wrapped around the rubber becomes an ellipse so that some rays that enter the optical fiber can be transmitted and some cannot be transmitted (loss). The transmitted light has an angle of incidence greater than the critical angle so that perfect reflection occurs. When pressed there are some rays whose angle of incidence is smaller than the critical angle so that loss occurs.
This results in a decrease in the transmittance value. The light loss event can also be seen with the clearer light scattered when the optical fiber is pressed. Also, the greater the number of turns, the steeper the gradient of the line. This is because the greater the number of turns of the optical fiber when under pressure, the more light loss points will be.

Figure 5. Conditions when the optical fiber is stressed

The difference between the light loss values at each press the greater as the curvature value increases. This shows that the optical fiber is at the limit of its deformation. If the optical fiber is pressed continuously, the curvature value will be greater. This causes the optical fiber to suffer damage in the area with large curvature values. If the optical fiber is still emphasized, the optical fiber will break.

Figure 6. Flood early warning system design with fiber optic.

4. Conclusion
The research that was succeeded made fiber optic sensors that can detect water level using the macro bending method, where the smaller diameter of the optical fiber macro bending, due to greater light loss, the resulting loss is also greater, this is in accordance with the results of the research. The results obtained are that the more turns cause greater the light losses generated when macro bending occurs. The results
of the optical fiber compression treatment of 3.2 - 2 cm with an R² value of 0.8765. It can be said that this research has the potential to become a flood sensor.

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