The influence of curvature configuration on the characteristic of alcohol gel insertion jacket of polymer optical fiber liquid level sensor

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Abstract: This study aimed to determine the effect of curvature configuration to sensitivities and linearities of Polymer Optical Fiber (POF) water level sensor. POF type SH-4001-1.3 has been used in this study. The jacket of POF of 20 cm was removed. Transparent piped inserted by alcohol gel has been used to replace the jacket. This is head of a sensor. The head of a sensor is curved with variations of the specified path length, peel length, the width of curvature, the height of curvature and waveform. Configuration A (20 cm, 34 cm, 6 cm, 2 cm, 1 wave), configuration B (20 cm, 34 cm, 8 cm, 2 cm, 1 wave), configuration C (20 cm, 34 cm, 9 cm, 2 cm, ½ wave), configuration D (20 cm, 34 cm, 10 cm, 2 cm, ½ wave). The head of a sensor inserted into the water tank. The light source inserted to one end POF is a He-Ne laser light with a power of 5 mW and a wavelength of 632.8 nm. Power output at the other end received by the Optical Power Meter (OPM). The curvature configuration the head sensor of POF affects the output. Configuration A has good sensitivity, however good linearity given by configuration.

Keywords: POF, sensor, curvature

1. Introduction
Optical fiber technology has a very important role in the telecommunications industry. Optical fibers now have usability in remote sensing. The optical fiber is used as a sensor to measure level sensors petrol [1], liquid levels [2-4], the level of the liquid in a volumetric flasks as applications in industry [5], strain measurement [6], the humidity sensor in storage chemical [7,8], and temperature sensors [9,10].

On the other hand, optical fibers have been used for measuring water level in many forms, some are non-intrusive sensors based on light attenuation while passing tank walls as in [11], but being only useful in transparent tanks [7]. The industrial world needs a tool to measure the water level in a large tank. The optical fiber is the only part of the measuring device that introduced into the tank – that is, only light and plastic or glass interacts with the water – the method becomes safe and corrosion free, without electrical sparks that could cause a fire or explosion of a tank [12]. Plastic optical fibers (POF) have received increasing attention because of their clear technical advantages over glass fibers, such as flexibility and large core diameter, which enables efficient connection and coupling resulting in a low-cost system for a local area network [13]. POF has a higher numerical aperture than glass optical
fibers, and the system also has the advantage from a wider acceptance angle which provides a better light collecting conditions [14].

Fiber optic sensor used a modified behavior of light waves. Methods for modifying can be done against the amplitude (intensity), frequency, and phase [15]. Amplitude modification has the advantage of being easy to be processed [9,16-20]. This method is a simple method. Intensity changes occurred due to the leakage caused by the optical fiber subjected to pressure, temperature[10] changes, bending [20] or other physical treatment

This research examined the sensitivity of changes in the intensity of the POF sensor which has multiple bends and using water level sensor with fiber optic in a sinusoidal configuration which has been inserted gel. Here, the variations of fiber optic configuration are the length of the track, the length of peeling, the width of curvature, curvature height, and waveform, respectively.

2. Experimental Set-Up
The research was to find the effect of the curvature of the POF cladding and coating of optical power received by OPM. As is well known, not only used in communications systems, but also plastic optical fiber has been widely used as a sensor. In this study, POF was used as a water level sensor. POF type SH-4001-1.3 has a core refractive index of 1.49 and the cladding refractive index of 1.41. Design of fiber optic experiment contained in Figure 1.

![Figure 1. Design a research tool](image)

Description: (a) Optical Power Meter (OPM); (b) Fiber Optics; (c) Water storage containers; (d) Helium-Neon Laser

Table 1 represents the configuration of the fiber optic specifications.

| Specifications                  | Optical fiber configuration |
|---------------------------------|----------------------------|
|                                 | A  | B  | C  | D  |
| Length Tracks (cm)              | 20 | 20 | 20 | 20 |
| Long Exfoliation (cm)           | 34 | 34 | 34 | 34 |
| curvature width (cm)            | 6  | 8  | 9  | 10 |
| High-curvature (cm)             | 2  | 2  | 2  | 2  |
| Form (wave)                     | 1  | 1  | ½  | ½  |

![Design Picture](image)
3. Result And Discussion

In the particular study, the optical mechanism was done on POF to perform intensity modulation. Intensity modulation was done by measuring the optical power output fiber by modifying the state of the optical cladding. Research-based water level sensor sinusoidal-shaped POF included in the classification of intrinsic fiber optic sensors where the next POF as a guiding light once served as the sensing the water level in certain parts of the POF. The research result is presented in Figure 2 which is a graph in each configuration. The increase in altitude (independent variables) were conducted nine times, i.e 4 cm, 6 cm, 8 cm, 10 cm, 12 cm, 14 cm, 16 cm, 18 cm and 20 cm. The light source Helium-Neon laser used have $\lambda = 632.8$ nm and power of 5 mW.

Figure 2 shows that the optical power (dBm) that has been detected by the OPM to the water level (cm) in each normalized width curvature. Normalization was done by dividing the score of optical power at every level rises with the highest absolute score of optical power. This study measured the amount of optical power loss resulting from the different configuration curvature. The loss of power due to the treatment granted by the characteristics of optical fiber, which will be weakened when bending or coating on the cladding.

![Figure 2](image-url)

**Figure 2.** Graph normalized combined power output (a.u.) to the water level (cm) with a wide variety of curvature

Figure 2 shows when the water level changes, there will be a change in the optical power in spite of these changes are very small. Optimal data obtained at the time of configuration C. Figure 2 is a graph of the optical power normalized by the water level. The x-axis shows water level, with the unit of cm while Y-axis shows normalized power output with the unit of a.u.

The sensitivity and linearity of the liquid level sensor is a change in the output sensitivity to any changes in the smallest input. For linear elements, the determination of the sensitivity is the gradient ($\Delta y / \Delta x$) or the slope of the graph. Sensitivity analysis is a technique to assess the impact of various
changes of each key variables toward the result. Determination elements sensitivity is obtained by appeared gradient when applied to fitting using origin. The linearity test aimed to determine whether the two variables have a linear correlation. By using origin, it has obtained regression score of the linear fitting result. Simple regression analysis is a correlation between two variables; they are independent variable and the dependent variable. Linearity can be stated in a straight line equation. Table 2 shows a score of sensitivity and linearity.

| Configuration | Sensitivity (dBm/cm) | Linearity |
|---------------|----------------------|-----------|
| A             | -0.056               | 0.98      |
| B             | -0.036               | 0.96      |
| C             | -0.018               | 0.99      |
| D             | -0.040               | 0.98      |

The negative sign indicates that the line on the graph tends to the left. The best sensitivity is presented in Figure 3 which shows a combination of graphic on each configuration.

**Figure 3.** Combined graph of wide variations for each configuration

The best sensitivity obtained in Configuration A with the curvature of 6 cm width with a score of
0.056 dBm/cm. It means when there is a change in the water level, there will be a change in the optical power. Table 2, shows the linearity of the optical fiber in the form of sinusoidal, with the variation of Configuration A, Configuration B, Configuration C and Configuration D with the score close to 1. Best linearity obtained in Configuration C with a linearity coefficient of 0.99 which means that there is a linear correlation between the light intensity and the increasing of the water level.

4. Conclusions
The coating on the cladding on each optical fiber curvature configuration could provide the output of POF because of the differences of reflection on the coating material. Reflection on curved POF occurs when the light hits the boundary of core-cladding and cladding-water. The light intensity score as the output of sinusoid optical fiber in each curvature will be smaller as the water level increases. Best sensitivity obtained in Configuration A while best linearity is Configuration C.

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