HYDROCARBON CONCENTRATION MEASUREMENT BY USING FIBER OPTIC DISPLACEMENT SENSOR

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Dedicated to my late father, Ab Munap bin Selangkah
the greatest mother, Bechek binti Bilak
and my brother, Daing Hassanal Sofri bin Ab Munap

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ABSTRACT

Hydrocarbon is an organic water pollution. It can harm the environment as well as human being. Therefore a feasible way should be identified to detect the hydrocarbon level in water. In this study a fiber optic displacement sensor was introduced as a technique to determine the concentration of hydrocarbon in water. A reflective configuration technique was developed and the concentrations of hydrocarbon were studied in the range of 0% to 20%. In order to validate the system two unknown concentrations were selected representing the lower region and the higher region. In principle this sensor is using the concept of intensity modulation as a function of displacement. The optimum displacement between the reflecting target and the fiber optic probe was found to be at 1.5 mm for all the concentration tested. The intensity of light received by sensor was connected to a voltmeter. The voltage measured from different hydrocarbon concentration was initially calibrated by displacement measurement. The fingerprint for hydrocarbon solution was revealed in the calibration curve which had fast response in the front part and a slow response at the back part. The peak voltage from each fingerprint was found to be inversely proportional to the tested concentration. This means the higher concentration of hydrocarbon the weaker is the signal detected. The sensitivity of the fiber optic displacement sensor was found to be 0.12 mV/wt% with a repeatability of 96%. The resolution of the sensor was 0.027 mV, with a limit of detection of 0.23%. The linearity index was found to be 93.9% for 6% hydrocarbon concentration and 105.2% for 14% hydrocarbon concentration. The simplicity and the creditability of such system offer a good opportunity for industrial applications in the environmental sector.

ABSTRAK

Hidrokarbon adalah pencemaran air organik. Ia boleh menyebabkan pencemaran alam sekitar dan kehidupan manusia. Oleh itu cara yang sesuai perlu dikenalpasti untuk mengesan tahap hidrokarbon di dalam air. Dalam kajian ini pederia sesaran serabut optik diperkenalkan sebagai teknik untuk menentukan kepekatan hidrokarbon di dalam air. Teknik konfigurasi pembalikan dibangunkan dan kepekatan hidrokarbon dikaji dalam julat 0% hingga 20%. Untuk menentusahkan sistem, dua kepekatan yang tidak diketahui dipilih bagi mewakili kepekatan yang rendah dan kepekatan yang tinggi. Secara prinsipnya, penderia ini menggunakan konsep modulasi keamatan berfungsikan sesaran. Sesaran optimum antara sasaran pembalikan dan penduga serabut optik yang diperoleh adalah 1.5 mm bagi kesemua kepekatan yang diuji. Keamatan cahaya yang diterima daripada penderia dihubungkan kepada voltmeter. Voltan yang diukur daripada kepekatan yang berbeza ditentu ukur dahulu terhadap ukuran sesaran. Satu pengesahan identiti bagi hidrokarbon telah diperoleh berdasarkan lengkung kalibrasi yang mempunyai tindak balas yang pantas pada bahagian hadapan dan tindak balas yang perlahan pada bahagian belakang. Voltan puncak daripada setiap pengesahan identiti didapati berkadar songsang terhadap kepekatan. Keadaan ini bermakna semakin tinggi kepekatan semakin lemah isyarat yang dikesan. Sensitiviti penderia sesaran serabut optik adalah 0.12 mV/wt% dengan kadar 96% keboleh-ulangan. Resolusi penderia ialah 0.027 mV dan batas pengesanan ialah 0.23%. Pencapaian indeks kelinearan ialah 93.9% bagi kepekatan hidrokarbon 6% dan 105.2% bagi kepekatan hidrokarbon 14%. Kemudahan dan kebolehan sistem seumpama itu menawarkan satu peluang baik bagi penggunaan industri contohnya bagi sektor alam sekitar.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Water pollution is seen as one of the biggest challenges for people all over the world. With current world population has reached over 7 billion, it is a major concern for scientist as well as world community for the quest of clean water. In our globalize world today, growing demands drive to rise of industries, which in turn causes improper disposal of wastes into the water sources (Yasin et al., 2008). Hydrocarbon has been identified as an organic pollutant in water. As pollutants, they are of concern due to the potential adverse effect they poses on our environment and harmful to human when being used. Therefore, research on Hydrocarbon level measurement in water has created massive attention from researchers all over the world. Fiber optic sensor is seen as one of the significant sensor for detection of Hydrocarbon concentration in water.

The breakthrough of optical fiberbased sensor has developed variety form of physical sensors for a wide range of physical parameters. Physical parameters such as displacement, pressure, temperature, and electric field detected by using optical fiber sensors indicate very high performance when being compared with conventional transducers (Yasin et al., 2012). Fiber optic based-sensors also have been demonstrated as an effective sensor for measuring chemical quantities such as pH, refractive index, and concentration of solution (Harun et al., 2010).

In this project, Fiber optic displacement sensor is employed to measure hydrocarbon level in water. The sensor operation is based on the intensity modulation technique using a plastic optical fiber-based bundle as a probe and a flat mirror as the reflecting surface which in turns offer simplicity, reliability, and continuous measurements capability. The Fiber Optic displacement sensor uses a 633 nm He-Ne laser as a light source due to its high absorption of Hydrocarbon within that wavelength. Different concentration of Hydrocarbon exhibits different output voltage which is affected by the intensity of light passing through the solution of Hydrocarbon.

1.2 Recent Progress

Fiber optic sensoris widely used to measure properties of environment. It can measure anything which changes the way light travels through the fiber, or alters the light's properties. Recently, fiber optic sensors have received tremendous attention for application used for measurements of physical and chemical parameters. This is due to its attributes such as its small size, wide frequency response, immunity to electromagnetic interference, and low-cost system(Noriah et al., 2013). Fiber optic sensor is a fiber based device used to sense some quantity such as vibration, displacement, and pressure. The general principle of fiber optic sensor is that light from a laser is sent through an optical fiber. The optical fiber will then experience some changes of its parameters and reaches a detector arrangement which measures these changes.As Hydrocarbon can be very inflammable, fiber optic sensor makes it feasible to be used during Hydrocarbon detection due to the fact that it does not produce sparks thus making it safe and suitable for application in remote area.

There are three distinct methods typically used for fiber optic sensors of displacement measurement; Laser interferometry, wavelength modulation, and light intensity modulation. Laser interferometry is based on fringe counting and has high resolution and stability of measurement. It is also known as phase modulated fiber optic sensor. Most interferometric fiber optic sensor use single mode fiber. This type of sensor uses variation of light for detection (Fidanboylu and Efendioglu, 2009). The working principle is that the field system will modify the optical phase of light channel through the fiber for detection purpose. By comparing the phase of light in signal fiber to that in a reference fiber, the phase modulation is considered to be detected interferometrically. The light is divided into two beams; one beam is exposed to the sensing environment and experiences a phase shift and the other is isolated from the sensing environment and is used for as a reference. Once the beams are recombined, they interfere with each other. However, its precision and stability are wavelength dependent (Huimin et al., 2007). Interferometer technique is also quite complicated even though it can provide very good sensitivity (Yasin et al., 2012).

Wavelength modulation use changes in the wavelength of light for detection (Fidanboylu and Efendioglu, 2009). Fluorescence sensors, black body sensors, and the Bragg grating sensor are examples of wavelength-modulated sensors. This type of sensor changes in frequency or wavelength to parameter of interest. It has low alteration of signal outside of sensing area. Wavelength measurement is very sensitive and not strongly affected by light loss in connections, or source intensity fluctuations. Characteristic reflected light wavelength relies on grating spacing. Stress applied to fiber changes spacing. Typically, wavelength modulation based sensor requires fiber Bragg grating (FBG) and optical spectrum analyser (OSA) for physical parameter and data acquisition. However these devices are costly.

Other common way used in fiber optic sensor is intensity modulation technique. Light intensity modulation is based on the comparison of the transmitted light intensity against the launch light which provides information on measurement of displacement between the optical probe and target. A multimode fiber as probe in fiber optic displacement sensor is most likely to be used in conjunction with intensity modulation technique. This is because multimode fiber probe has good coupling ability, large core radius, and high numerical aperture thus allowing probe to receive a significant amount of the reflected or transmitted light from a target (Yasin et al., 2008; Yasin et al., 2010). Intensity based fiber optic sensor is made by using an apparatus to convert measured parameters into a force that bends the fiber and trigger attenuation of the signal (Fidanboylu and Efendioglu, 2009). Absorption and scattering of the target also cause attenuation of signal, thus it can be deduced that intensity based fiber optic sensor depending on signal undergoing some loss. Intensity of light is also modulated by reflectance or changing the medium through which the light is transmitted. On the contrary to other sensing principles, the light intensity modulation shows a simple sensing preparation with reduced developing and operating costs. Although optical fiber bending and coupling misalignments can result in signal attenuation and light intensity instability, intensity-modulated sensors compete well with other sensing schemes and provide equally accurate results (Polygerinos, Seneviratne, and Althoefer, 2011).This result can be achieved with the use of additional optical fibers as reference fibers that compensate for transmission losses, fiber misalignments, and fiber bending.

In this research, reflective concept is used as a technique to transmit the light to be detected in fiber optic sensor. In term of wide dynamic range, fiber optic sensor with reflective configuration offers a promising solution for displacement measurement (Husna et al., 2013). The sensor probe is playing an important role with the selection of laser source and reflector. Normally, a probe with a pair of fibers is used as a media to transfer and collect the light to or from the target in a simple design of reflective fiber optic displacement sensor (Harun et al., 2012). Nowadays, researchers are paid more attentions in the development of sensor probe to improve the performance of fiber optic sensor. There are various configuration of fiber probe that gives significant influence on the performance of fiber optic sensor. A fiber optic probe which consists of one transmitting fiber core and 16 receiving fiber cores is used in this research. Previous theoretical analysis of 16 RF probes that showed good agreement with the experimental data with highest sensitivity (Yassin et al., 2012).

1.3 Problem Statement

Hydrocarbon contamination in environment is potentially widespread as modern society uses many petroleum-based products (Agency for Toxic Substances and Disease Registry, 2014). Hydrocarbon in water gives a significant impact on environment and life on earth. It is a major threat to human health when the water contaminated with Hydrocarbon is used by or comes in contact. A significant understanding and monitoring of Hydrocarbon level in water is crucial to ensure a sustainable environment and safe water for consumer. In general, Hydrocarbon concentration analysis is carried out using chemical method. However, it is time consuming and involves a lot of chemical substances. Therefore we need to find alternative way in a simple form, economical, and faster in determination of Hydrocarbon level in water.Fiber optic sensor is potentially capable to measure Hydrocarbon level in water. Fiber optic basedtechnology has provided a solution to the measurement of oil-in-water (Saini, D., Leclerc, R., and Virgo, M., 2001). Therefore, fiber optic sensor technology offers advantages to throw some light on this significant matter.

1.4 Research Objective

The main objective of this project is to determine the Hydrocarbon level in water. This is accomplished by the following:

i. To develop fiber optic displacement sensor system.
ii. To calibrate Hydrocarbon concentration in distilled water.
iii. To determine linearity index of the known Hydrocarbon concentration in distilled water.

1.5 Research Scope

In this study, a Helium-Neon of 633 nm laser was employed as a light source. Fiber optic sensor was employed as a probe. Light intensity modulated technique is the concept used in this probe. Light from He-Ne laser is coupled into a transmitting fiber and emitted at the end of the bundled fiber. A flat mirror is used to reflect the beam and send to the receiver. Displacement is a main parameter to verify the sensor. The range of displacement accomplished in this study is in between 0to 3.0mm as the fingerprint of Hydrocarbon concentration works effectively within this range. A Multimeter is used to measure the output of the probe associated with a photodiode as a detector. Lubricant oil is used as a hydrocarbon sample and diluted in distilled water. This is due to the fact that lubricant oil is a standard reference for Hydrocarbon measurement in a chemistry laboratory. The concentration of Hydrocarbon was tested within the ranged of 0 to 20%.

1.6 Thesis Outline

This thesis comprises of five chapters. The first chapter consists of the introduction and some overview of the research carried out regarding fiber optic sensors and technique used for sensing displacement. Research objectives and research scope is also stated to clarify the aim of research.

Chapter II is describes the theory of the research, which also reviewed some related works form previous studies. It consists of explanation concerning reflective configuration with light intensity modulation technique used in fiber optic displacement sensor. The detail is enlightened due to its significance role that makes up the whole system to function. Other than that, it also covers general knowledge of Hydrocarbon which acts as experimental sample in this sensor. All theories regarding fiber optic displacement sensor is further discussed in this chapter.

Chapter III explained the method and technique used in this research. Components of fiber optic displacement sensor that make up the whole system are explained in conjunction with their function and specifications. Other than that, preparation of Hydrocarbon samples in this research is described in detail in this chapter. It also covers the design, arrangement and working principle of the sensor systems that make up the system.

Details of Hydrocarbon level detected is enlightened in Chapter IV which is based on the result of the research. This chapter focused on performance of fiber optic displacement sensor based on peak voltage, sensing displacement, output signal and stability. Feasibility of fiber optic displacement sensor developed to measure known Hydrocarbon level in distilled water is further described at the end of this chapter.

Finally, the conclusion of the research was summarized in Chapter V. This chapter also highlighted the problem that occurred during the whole experimental work. A room of improvement and recommendation are suggested for future studies.

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