Underwater Oil Spill Imaging via UV LED-induced Fluorescence

Sangwoo Oh, Moonjin Lee

Maritime Safety Research Division

Korea Research Institute of Ships and Ocean Engineering (KRISO)

Daejeon, Republic of Korea

e-mail: swoh@kriso.re.kr

Abstract—**In this research, we describe the concept of underwater oil spill imaging technology based on the UV-induced fluorescence. This imaging system is composed of the ultraviolet LED (Light Emitting Diode) lights and the CCD (Charge-Coupled Device) image sensor. For the identification of the proposed imaging system, we conducted the lab-scale validation tests to classify the difference between the oil samples and the background. For the comparison between oil samples and seawater, we analyzed the images acquired from tests which were performed in different conditions. Through these tests, we can visualize the shape of underwater oil and also distinguish the oil samples from seawater. From this experiment using the proposed setup, we can confirm the possibility of this system for the underwater oil spill imaging system by UV LED-induced fluorescence.**

Keywords-Underwater oil; Oil spill imaging; UV LED; Fluorescence

I. INTRODUCTION

Oil spill incidents occur frequently at the sea, despite various efforts to reduce the oil spill from ships and underwater oilfield facilities. Spilt oil is very harmful for every organism in the ocean. For the reduction of oil spread on the ocean, rapid monitoring and exact analysis of oil spill are considerably essential.

Until now, a number of in-situ oil spill monitoring systems have been developed and some of them have been realized [1][2]. They can be largely divided into two parts by means of sensing mechanism. The first one is the sensor which uses the fluorescence method by UV (Ultraviolet) excitation [3] and another is the sensors using electrical capacitance detection by RF signals [4]. Theses sensors have the functions to analyze their components down to the ppb level. However, these sensors cannot get the image of underwater oil scene, but only detect the presence of oil in the seawater.

In the first step of oil spill accident, oil normally exists on the surface of seawater. But as time goes on, oil frequently forms the ball shape, so-called tar ball, and it goes down from sea surface. So, to identify the underwater oil spill like tar ball oil, it is essential to use the visualization tool for the identification of the underwater oil. In the case of oil spill from underwater oilfield facility, such as oil leak, the monitoring of underwater oil status is necessary for the prevention of it.

To achieve the visualization of the underwater oil spill, we propose a novel underwater oil imaging system which is based on the fluorescence phenomenon. This system is composed of the UV-LED (Light Emitting Diode) lights and the CCD (Charge-Coupled Device) image sensor. For the monitoring of the aquatic organism such as phytoplankton and coral reef, there are some researches which are related to the multispectral imagery in the sea [5][6]. However, in the case of underwater oil spill monitoring, there are a few studies.

In this research, we describe the novel underwater oil imaging system and an initial experiment to acquire the underwater oil image.

II. MATERIAL AND METHODS

A. Underwater oil spill imaging system

The underwater oil spill imaging system which is proposed in the research, is composed of the CCD image sensor (Basler scA1000-30gm) and UV-LED lights. In general, oils which consist of hydrocarbon compounds are excited by ultraviolet wavelengths (300-400 nm) and fluoresce in the visible wavelength range from 400-600 nm. The function of UV-LED lights is to excite the fluorescence of underwater oil. In this research the CCD image sensor is used to capture the fluorescence image of underwater oil. The CCD image sensor has a spectral range of 400 nm to 900 nm. For filtering the emission of reflected light from the underwater oil, we used the lens-type emission filter. The cutoff bandwidth of it is 400 nm. Most reflected light of fluorescent oil have the wavelength above 400 nm wavelength, so we used the emission filter having the cutoff wavelength of 400 nm. The numerical aperture of lens adapted to the CCD image sensor is 2.8.

B. Experiment

At the final development step of proposed imaging system, the water-proof housing is necessary. However, because the purpose of this experiment is to verify the sensing methodology which is newly suggested in this setup, we simplify the experiment condition. Figure 1 shows the experimental setup for the verification of the oil fluorescence by the proposed underwater imaging system. In this experiment, we used the bunker C oil samples

For the excitation of oils, we blocked the external lights (sunlight and artificial light) by a black box and only the UV LEDs can illuminate the oil samples.
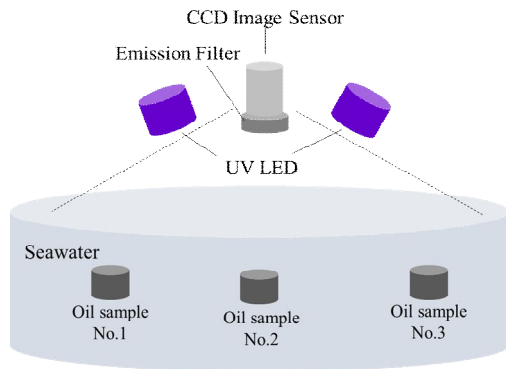
Figure 1. Experimental setup to identify the underwater oil spill imaging using UV LED-induced Fluorescence.

Figure 2. Fluorescent oil imageries acquired by CCD image sensor in the experiments (processed by MATLAB).

Three oil samples were contained in the cylindrical shape reservoir and the size of it is 3 mm (diameter) x 5 mm (height). This reservoir is made by polyethylene and it is transparent for the UV lights and visible lights. The reservoirs were put on the bottom of small scale basin which is filled with seawater.

In this research, we positioned the UV LED lights at the same position with CCD image sensor (see Figure 1), and captured the image of the fluorescent oil samples by the CCD image sensor. (see Figure 2).

For the quantification between oil samples and seawater, we analyzed the spectrum profile of captured images. Through it, we can see that the similarity level in this experiment is 92%. This analysis was performed in the total pixels of acquired image. These calculations of quantification process were performed by the verified image processing algorithm using MATLAB image process module.

From the processed result of the experiment, we can instinctively recognize the difference between the bunker C oil samples and seawater.

III.   RESULT AND DISCUSSION

In this research, we describe the novel underwater oil imaging system and an initial experiment to get the underwater oil image. For the verification of the proposed underwater oil imaging system, we conducted the lab scale experiments to identify the difference between oil samples and seawater.

For the quantification between oil samples and seawater, we analyzed the spectrum profile of captured images. Through it, we can instinctively recognize the difference between the bunker C oil samples and seawater. From this experiment, we can confirm the possibility of this system for the underwater oil spill imaging system by UV LED-induced fluorescence.
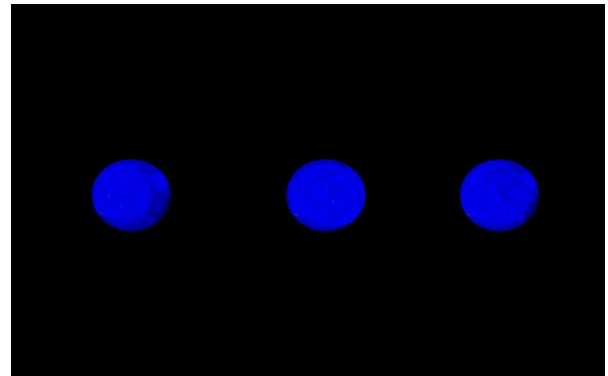
IV.   CONCLUSION

In this research, a novel underwater oil imaging system was suggested. The basic performance of the proposed system was identified by conducting the lab scale experiment using bunker C oil and seawater. From the result of this experiment we can instinctively recognize the difference between the bunker C oil samples and seawater. Although this experiment is on the first step among the whole development process, if we do some more development, we can expect that this suggested system can be applied to the underwater oil spill imaging system in real site.

REFERENCES

[1] A. MacLean, C. Moran, W. Johnstone, B. Culshaw, D. Marsh and P. Parker, "Detection of hydrocarbon fuel spills using a distributed fibre optic sensor," Sensors and Actuators A, vol. 109, 2003, pp. 60–67.

[2] G. Griffiths, "Review of oceanographic equipment and sensors for the detection and measurement of pollutants," Southhampton Oceanography Center Research and Consultancy Report, 2005, no. 99, pp. 1-24.

[3] C. Henry and P.O. Roberts, "Background fluorescence values and matrix effects observed using smart protocols in the Atlantic Ocean and Gulf of Mexico," International Oil Spill Conference, 2001, pp. 1203-1207.

[4] J. Andrews, "Automated marine oil spill detection system development update," Marine Environmental Update, US Navy SPARWAR Systems Centre, 1997, vol. 97, no. 1, pp. 1-10.

[5] A. C. R. Gleason, R. P. Reid and K. J. Voss, "Automated classification of underwater multispectral imagery for coral reef monitoring," Oceans 2007, Vancouver, 2007, pp. 1-8.

[6] D.G. Zawada, "Image processing of underwater multispectral imagery," IEEE Journal of Oceanic Engineering, 2003, vol. 28, no. 4, pp. 583-594.