Afyon Kocatepe Üniversitesi Uluslararası Mühendislik Teknolojileri ve Uygulamalı Bilimler Dergisi

Afyon Kocatepe University International Journal of Engineering Technology and Applied Sciences

AKÜ IJETAS Cilt **3(1)** (2020) Haziran (39-44 s) AKU J.Eng.App.Sci. **Vol 3(1)** (2020) June (39-44 pp)

Araştırma Makalesi / Research Article

e-ISSN 2667-4165 (https://dergipark.org.tr/akuumubd)

Mermer İşleme Tesislerinde Çamur Kontrol Sistemi İçin Optik Sensör Tasarımi

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GelişTarihi: 13/04/2020 ; Kabul Tarihi: 20/05/2020

Anahtar kelimeler
Optik Sensör Dizaynı; Temassız Ölçüm; Mermer İşleme; Çamur Kontrol Sistemleri.

Özet

Bu çalışma, mermer işleme tesislerinde çamur kontrol sistemi için hassas ve temassız bir optik sensör tasarımı ve imalatı geliştirmeyi amaçlamaktadır. Mermer tozunun devir daim sistemindeki konsantrasyon seviyesinin makinelere olası kalıcı hasarlar vermesini önlemek amacıyla sınırlı değerlerde tutulması gerekmektedir.Geliştirilen sensör sayesinde, mermer işleme makinelerinde kalıcı hasarlara yol açmadan, geri dönüşüm suyunda kritik çamur konsantrasyonu seviyesi kolaylıkla belirlenebilir. Tasarlanan sensörün farklı noktalardan yapılan ölçüm sonuçları, geri dönüşüm borusu üzerinde belirli bir konum gerektirmeden kolayca yapılandırılabileceğini göstermektedir.

An Optic Sensor Design for Sludge Control System in Marble Processing Plants

Keywords
Optic Sensor Design; Non-Contact Measurement; Marble Processing; Sludge Control System

Abstract

This study aims to develop a sensitive and non-contact optic sensor design and fabrication for sludge control system in marble processing plants. The concentration level of the dust in marble sludge must be kept in limited values to prevent possible malfunctions in the marble processing machines. Thanks to the developed sensor, the critic concentration level of sludge in recycling water can be determined without resulting any irreversible damages in marble processing machines. The measurement results of the designed sensor show that it can be configured easily without requiringdetermined position on the recycling water pipe.

1. Introduction

Digital technologies are being integrated into all areas of production systems and business. Due to the growing demand to urban life, the desire to use natural materials in buildings is also gradually increasing. Therefore, there is seen an increase in the use of marbles in buildings especially as decoration materials. Hence, the huge production demand in this area requires new solutions for marble processing (MP) plants (Cetin 2003, Onargan et al.1997, Mollah et al. 2004).

One of the prior needs of the MP plants is to re-gain waste-water. Because, clean water must be provided continuously at constant flow to obtain with sufficient quality products from the tile and wipe polishing lines in MP plants (Senturk et al.

1996). Depending on the capacity, in a production facility quite high amounts of water ranging from 100 m^3/h to 500 m^3/h are consumed (Buyuksagis and Emrullah 2003). Thus, it is very important to re-purify the wastewater and re-gain it for processing in MP plants (Onenc 2001, Ersoy 2003).

In marble waste-water can be seen rich solid particles (Kavakli 2003). Some methods including the natural precipitation method or the physicochemical processes following chemical coagulation-flocculation-precipitation processes are widely used to re-use waste-water resulting from MP (Ryan et al. 2008, Duan and Gregory 2003). These methods are very effective in the treatment of colloidal particles and waste-water containing dissolved organic matter (Mollah et al. 2001). In general, coagulation is the process in the solution including colloidal matters, which follows precipitation after the collision of the charged particles with opposite ions and neutralization. The disadvantage of this process is the presence of anions forming an acidic medium by combining with the added metal coagulants. In addition, filtering of wastewater by membranes is another method as a filtration technique (Alfonso et al. 2002).

The objective of this study is to design and fabricate an optic sensor to measure concentration of marble dust in recycling water. Hence, it will be easy to design automatic sludge control system in MP plants. By using a control system with the sensor can be measured cleaning degree of the wastewater passing through filtering process, whether its degree reaches a sufficient level of purity, and if not, sends the wastewater back and warns the filtering station and that performs the same process again until sufficient cleaning degree is achieved.

2. Materials and Methods

The designed sensor and established test-bed is explained in this section.

2.1 Measurement System

The designed measurement system consists of two parts of a reflecting optical sensor coded with TCRT 5000 (L). It is decomposed into two sections and mounted into a metal pipe section mutually.

In part 1 (upper part in Fig. 1), there is a LED emitter circuit with a power of 100 mW that emits IR light at 950 nm wavelength. In part 2 (lower part in Fig. 1), there is a receiving photodiode as a sensor that detects the IR light. A schematic representation of the sensor is given in Fig. 1. The light emitted from the IR-LED passes through the wastewater flowing in the pipe and reaches the optical sensor (photodiode) on the opposite side. The measurement system determines pollution rate of wastewater of the MP. There is a relationship between passing light intensity and the wastewater thickness.

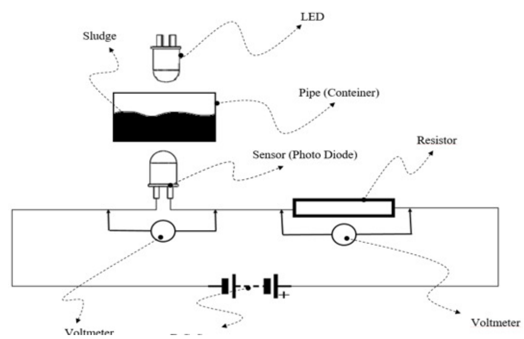

Figure 1. The schematic representation of the designed measurement system

2.2.Operating Principle of the Optic Sensor

There is a relation between the decrease in the intensity of the passing light and the thickness of the flowing wastewater in accordance with the Beer-Lambert law. The absorption of radiation by materials obeys the law(Aydin 1982, Wypych 2018),

$$log_{10}\frac{I_0}{I} = A \qquad (2.1)$$

whereI_0 is the intensity of incident beam and I is intensity of transmitted beam, respectively.

If the measurement environment is aqueous solution, absorbance medium (A) will be;

$$A = abc \qquad (2.2)$$

where; a is the molar absorption coefficient (absorptivity), b is the path that light travels in aqueous solution, and c is the concentration of the absorber.

Based on this principle, the concentration values existing in wastewater can be saved as instantaneous data, and it can be ensured that the wastewater concentration is kept below a specified limit value. Also, the absorption coefficient of the solution can be obtained. The absorption coefficient μ is related to absorbent as follows:

$$A = \mu h \quad (2.3)$$

Here, h is the path travelled by light in the medium. If the Eq.(2.2) is equalized to Eq.(2.3) then μ is found as;

$$\mu = ac \quad (2.4)$$

It can be easily seen that $h = b$. Thus, the absorptivity is directly proportional to the absorption coefficient and changes with concentration.

2.3. Determination of the Wastewater Thickness

The used test-bed for the developed measurement and control system is shown in Fig.2. The numbers in the figure; 1,2,3 and 4 show the measurement points. Also, a metal barrel which has 200 L volume is used for the recycle water.

Figure 2. Test-bed for the measurement system

A schematic representation of the vertical circular section of the measurement device is shown in Fig. 3 (Aydin 2016). In this figure, h_1 and h_2 are waste-water thicknesses for two distinct states. The meaning of $h_1 < \alpha$ is less filled, and $h_2 > \alpha$ is represent much filled condition. α is the radius. The dark colorized area represents the wastewater in the pipe.

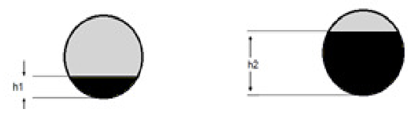

Figure 3. A schematic representation of the vertical circular section of the measurement device

If the length of the prototype is l and S is considered as the area of the filled part of this vertical section, the volume of liquid inside is given by

$$V = Sl \quad (2.5)$$

The dependence of the surface S on the wastewater thickness is

$$S(\gamma) = \alpha^2 \left(\cos^{-1}\gamma - \gamma\sqrt{1-\gamma^2}\right) \quad (2.6)$$

where γ is given as

$$\gamma = 1 - h/\alpha \quad (2.7)$$

h represents the thickness measured from the bottom and changes within the $0 \le h \le 2\alpha$. When the prototype is completely filled with wastewater $h = 2\alpha$, and $h = 0$ when it is completely empty. Thus γ is in the range $-1 \le \gamma \le 1$. Hence, Eq.(2.6) can be written as approximately

$$S(\gamma) \cong \frac{\pi\alpha^2}{2}(1-\gamma) \quad (2.8)$$

From the Eq.(2.5) and (2.8)

$$h = \frac{2V}{\pi\alpha l} \quad (2.9)$$

The thickness can be calculated via the volume, or vice versa, if the thickness is known, then the instantaneous volume (flow) can also be calculated.

2.4. Experimental Setup

Marble sludge (powder) is supplied from the Metaş® MP plant in Akhisar-Manisa-Turkey. Samples are prepared as 50 ml, 100 ml,..., 700 ml for each concentrations of 0%, 5%, 10%,..., 50%, respectively. The measurement data of the prepared samples are saved using by the fabricated contactless optic sensor which is shown in Fig.4. It is located suitably to a metal pipe through which wastewater can flow.

2.5. Measurement in Constant Flow Rate

The measurement sensor setup is shown on the pipe in Fig. 4. The pure water is withdrawn from the barrel and sent back to the barrel with the help of a circulation pump connected to the experimental setup. The flow rate of the pump is adjusted to the 200 L / min. Firstly, the data in case of pure water are collected from thedetermined four measurement points. Then, 150 g of the marble mud is added the circulation system.

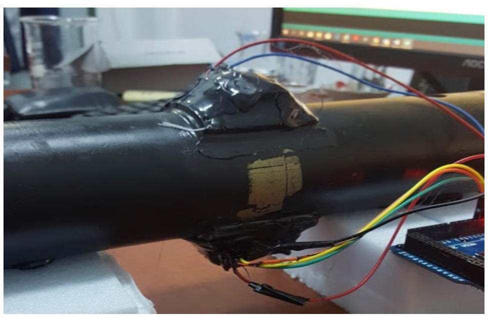

Figure 4. The measurement sensor setup

3. Results and Discussion

The absorbance values are measured according to the solution thickness depending on the percent concentration of the marble sludge solution at zero flow without any flow.It is clearly seen that the absorbance values increase with concentration. It is also observed that the absorbance values increase with increasing volume and corresponding thickness. In Table 1, measured absorbance values are given. The data are proportional to the analog signal received at the circuit output according to the volume (V) or the corresponding thickness (h) value of the marble sludge solution in the prototype at different concentration values. Also, Table 1 data are shown as a graph in Fig.5.

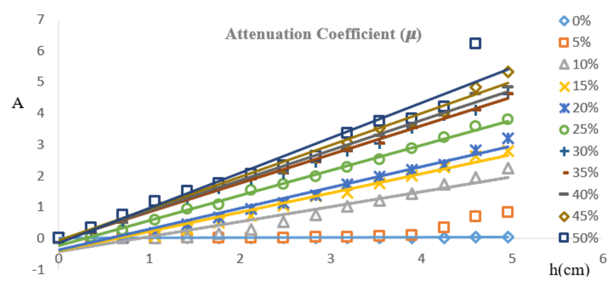

Figure 5. The attenuation coefficient

Table 1. Absorbance values

Volume (mL)	Thickness (cm)	Concentration of Solution (%) 0	5	10	15	20	25	30	35	40	45	50
0	0,000	0,020	0,020	0,021	0,020	0,021	0,022	0,020	0,022	0,021	0,022	0,022
50	0,354	0,021	0,023	0,024	0,027	0,028	0,034	0,188	0,188	0,336	0,352	0,358
100	0,708	0,022	0,024	0,032	0,034	0,037	0,275	0,498	0,498	0,521	0,754	0,766
150	1,062	0,022	0,025	0,032	0,082	0,178	0,598	1,055	1,055	1,041	1,172	1,178
200	1,415	0,022	0,026	0,039	0,296	0,465	0,944	1,311	1,311	1,329	1,406	1,525
250	1,769	0,023	0,028	0,143	0,503	0,681	1,084	1,585	1,585	1,702	1,735	1,763
300	2,123	0,023	0,029	0,298	0,739	0,949	1,543	1,884	1,884	2,015	2,015	2,060
350	2,477	0,024	0,031	0,526	1,047	1,125	1,740	2,083	2,083	2,115	2,264	2,322
400	2,831	0,026	0,033	0,756	1,344	1,390	1,979	2,428	2,428	2,571	2,610	2,637
450	3,185	0,027	0,039	1,028	1,459	1,740	2,264	2,800	2,800	2,850	3,056	3,372
500	3,539	0,027	0,060	1,211	1,763	1,965	2,533	3,036	3,036	3,290	3,526	3,750
550	3,892	0,030	0,105	1,430	2,008	2,200	2,867	3,526	3,526	3,595	3,750	3,837
600	4,246	0,032	0,341	1,740	2,274	2,353	3,239	3,932	3,932	3,932	4,037	4,220
650	4,600	0,036	0,699	1,951	2,623	2,833	3,595	4,094	4,094	4,625	4,848	6,234
700	4,954	0,035	0,834	2,245	2,800	3,214	3,792	4,625	4,625	4,848	5,318	-

As a result of the experimental measurements illustrated in the Fig. 5, the changes in the experimental absorbance values according to the wastewater thickness calculated via Eq.(2.9) at the pre-determined concentration values given in Table 1. The slopes of the lines found by fitting the plots give attenuation coefficients μ.

Table 2. The coefficients

c (%)	μ (cm^{-1})	a (cm^{-1})
50	1,12	0,022
45	1,013	0,023
40	0,964	0,024
35	0,917	0,026
30	0,917	0,031
25	0,800	0,032
20	0,665	0,033
15	0,614	0,041
10	0,474	0,047

Table 2, the absorptivity values calculated with the using of Eq.(2.4). As the proportion of marble powder in the solution increases by mass, the absorptivity of the solution also increases.

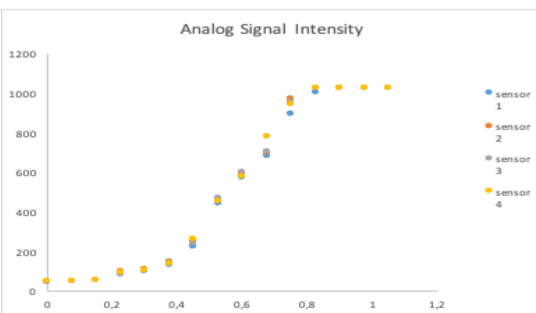

Figure 6. Measurement data from the setup

On the other hand, in the experimental setup that provides a constant flow rate, different sensor positions are identified and numbered in Fig. 4. As can be seen from Fig. 6, there are no obvious differences between the data read from the sensors. Thus, it can easily be said that the measurement point don't depend on the anywhere of the recycle water pipe.

Table 3. Measurement values obtained by changing the density (concentration) in the constant flow rate for four different measurement points

Mass		Analog Value			
Sludge (gr)	Per. (%)	Sensor 1	Sensor 2	Sensor 3	Sensor 4
0	0	45	46	45	46
150	0,075	48	46	48	48
300	0,150	51	54	54	56
450	0,225	88	96	80	90
600	0,300	102	110	98	100
750	0,375	130	146	140	137
900	0,450	220	250	240	260
1050	0,525	440	460	470	450
1200	0,600	570	585	596	575
1350	0,675	680	695	702	780
1500	0,750	890	970	950	940
1650	0,825	1002	1024	1024	1024
1800	0,900	1024	1024	1024	1024
1950	0,975	1024	1024	1024	1024
2100	1,050	1024	1024	1024	1024

4. Conclusions

One of the main conclusions of the study is designed an optic sensor which enables us to measure MP processing dust in a recycling wateras contactless.

Another useful conclusion is that a special localization for mounting this device to a system will not be needed. This shows the marked superiority of the designed control unit or flowmeter over other flow meters.

Acknowledgements

The authors present their special thanks to the ManisaCelal Bayar University Scientific Research Projects Commission for the supports of the study under project number 2017-063.

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