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Development of a Real-Time Smoke Belching Monitoring System for Public Utility Vehicles (PUV) via GSM

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Abstract - *The Development of a Real-Time-Based Smoke Belching Monitoring System for Public Utility Vehicle is designed in order to monitor smoke belchers or violators among public utility vehicles (PUV) that uses diesel such as jeepneys or buses. The concept of the project is to measure the opacity of the smoke being emitted by the PUV with the use of a predesigned sensor unit incorporated by Light Dependent Resistor Sensor and Light Source facing each other, 4 inches apart. By allowing the smoke to pass through the LDR and Light Source, the desired resistance is acquired and processed by the microcontroller to obtain the Light Absorption Coefficient. This value is the basis for being a smoke belcher (If it exceeds 2.5 k). The system then sends the data (Plate Number and K -value) for every one (1) hour to the Database System and to the operator with the aid of GSM Microcontroller that leads to a real time monitoring. The system is possible to implement and has a potential to be used for emission testing centers since it has the features of the commercial opacity meter which is common in emission centers to measure the smoke emitted by the diesel-fueled vehicles. This project serves as an innovation in emission testing because it monitors the smoke belchers in real-time and operators or owners of the vehicle are not required anymore to go to the emission testing center every year to renew their car registration.*

Keywords: *Smoke belching, emission test, opacity meter, public utility vehicles*

INTRODUCTION

Smoke belching is the vigorous discharge of smoke from the vehicle's pipe and considered as number one contributor to air pollution[1]. Public and private smoke analyzers are used to measure the number of air pollutants of a particular vehicle engine into the air[5]. These analyzers measure diesel and gas-fueled vehicles with different particles and chemicals such as carbon monoxide, carbon dioxide, hydrocarbon that could affect or even destroy the respiratory system. Although portable testers are very expensive, the Philippine government still uses it to periodically conducts a roadside inspection wherein they randomly selects vehicles and perform on-the-spot testing using portable emission analyzers, still numbers of smoke belchers become bigger.

An ideal engine produces an amount of air and fuel into its combustion chamber and burn at a right time produces a clear and white smoke. In the contrary, [9] vehicles that emit more amounts of gases and pollutants are those containing disturbed valve and injection timing. This results to an incomplete combustion and therefore produce more amounts of pollutants and gases that produces black smoke. To test the carbon particles of exhaust of any Public Utility Vehicles (PUV), the beam of light passes directly across the smoke; the small amount carbon transmitsthe light through the smoke, the more carbon particulates do not allow the light to pass through. Thus, by measuring opaqueness of smoke with the help of an opacity meter, the quantity of unburned fuel in the exhaust of diesel engines can be estimated.

This paper covers the real-time monitoring for smoke belching of public vehicles (i.e. jeepneys and buses) using diesel that emit an amount of density or opacity of the smoke and did not cover other

chemicals and compound elements in emission testing. [8] The Light Absorption Coefficient (LAC) is measured with the acceptable value of 2.50. The device will tell if the vehicle passed or failed the emission test. The working temperature of the Light Dependent Resistor (LDR) is only at 60 degrees Celsius and below[2]. And the sensor is more sensitive in moist and wet environment.

The overall objective of the study was to develop a portable and low cost monitoring system of smoke belching and thereby transfer this technology to the local government and industry. This is the first in the Philippines, to have an opacity meter that is controlled by microcontroller and GSM to monitor and record the measured light absorption coefficient value of any Public Utility Vehicle.

RELATED WORKS

The Clean Air Initiative for Asian Cities Center (CAI-Asia Center), Coalition of Clean Air Advocates (CCAA) and Partnership for Clean Air (PCA) prodded the new administration to strengthen the assessment and maintenance system of public utility vehicles and take the rolling coffins off the road[3]. During a public hearing organized by the Land Transportation Office, representatives of transport organizations in the Metro expressed that the government will be hard-pressed to find a fleet of public utility buses or jeepneys that would pass the emission standards set under the Clean Air Act upon inspection[6]. The maintenance component of motor vehicles should consequently be emphasized.

Baylon, Dy, Quidilla and San Pascual [9] conducted a study that defined opacity as the amount of light covered by particle pollution in the atmosphere. Using a light source (LED) and light dependent resistor, they were able to measure the opacity. The measure of the resistance of the LDR depends on the light that it receives when opaqueness of the smoke passes between the light source and the LDR. The smoke sample from the PUV is passed through a funnel-shape exhaust made out of aluminum sheet. The amount of light that passes through determines the darkness or opacity of the smoke. The light source and a Light Dependent Resistor are strategically integrated on the exhaust so that smoke passes between them. The resistance of the LDR inversely varies with the amount of light being fed to it.

A study authored by Hoon [11] defines the major difference between microcontroller and microprocessor. The microcontroller consists of Central Processing Unit (CPU), memory devices (ROM and RAM), input and output ports and timer embedded into a single chip. It also has many on-chip facilities such as serial port, counters, analog to digital converter and interrupt control so that they can be interfaced with hardware and control functions of many kinds of presentation. It is ideal for many applications in which cost and space are critical.

The emission testing centers test public utility vehicles' opaqueness of the smoke using opacity meter as stated by a number of the studies. It is also defined by some of the literature that the main part of the opacity meter is the Light Dependent Resistor (LDR) that converts light in to electrical energy. The LDR is a light sensitive device used to state the presence or absence of light[4]. It is also discussed in the literature and studies that the opacity meter measures the light absorption coefficient. It is done when the smoke passes in between the light depended resistor and the light emitting diode (LED). It is stated also in the studies that the maximum value of light absorption coefficient is 2.50. And beyond the maximum value is smoke belching.

Operation

The researchers utilized digital signal process that converts light into an electrical signal called photoelectric effect. It is the emission of electrons of any metals when it triggers light. These electrons are called photoelectrons. According to the electromagnetic theory, the effect can be connected from the energy produced by the light to the metal. Moreover, it is expected to have a dim light to present a lag time from initial shining of light and the electrons it emit.

The photoelectricity converts light energy into electrical energy through three different phases: (1) photoconductive, (2) photovoltaic, and (3) photoemissive [10]. The researcher used photoconductive effect where light reduces the resistance of a metal by making the electrons inside it more mobile.

Photo-resistors or the Light Dependent Resistors (LDRs) are very useful especially in sensor circuits that use light and dark sensors[7]. The resistance of LDR is very high; sometimes as high as 1000 kilo-

ohms. But when the LDRs are exposed to light, resistance dramatically drops in its value.

The absorption coefficient regulates how far into a material light of a particular wavelength can infiltrate before it is captivated [8]. Light is poorly absorbed if the material has a low absorption coefficient, and it appears transparent to that wavelength if the material is thin enough. Semiconductors have an outstanding reading in its absorption coefficient, hence the light that produces energy below the band gap does not have enough energy to produce electrons from the valence band to conduction band; consequently this light is not absorbed.

The intensity or the opacity of smoke that passes through the opacity meter is measured indirectly by measuring the change in the resistance of the LDR before and after the light passing through the exhaust of given thickness [3].

So, the formula in terms of resistance is:

$$\mathbf{Rx = Roe\alpha x} \qquad \text{eq. 1}$$

where: Ro is the resistance at x = 0,
Rx is the resistance at a distance x
X is the thickness
From equation 1 the absorption coefficient is given by

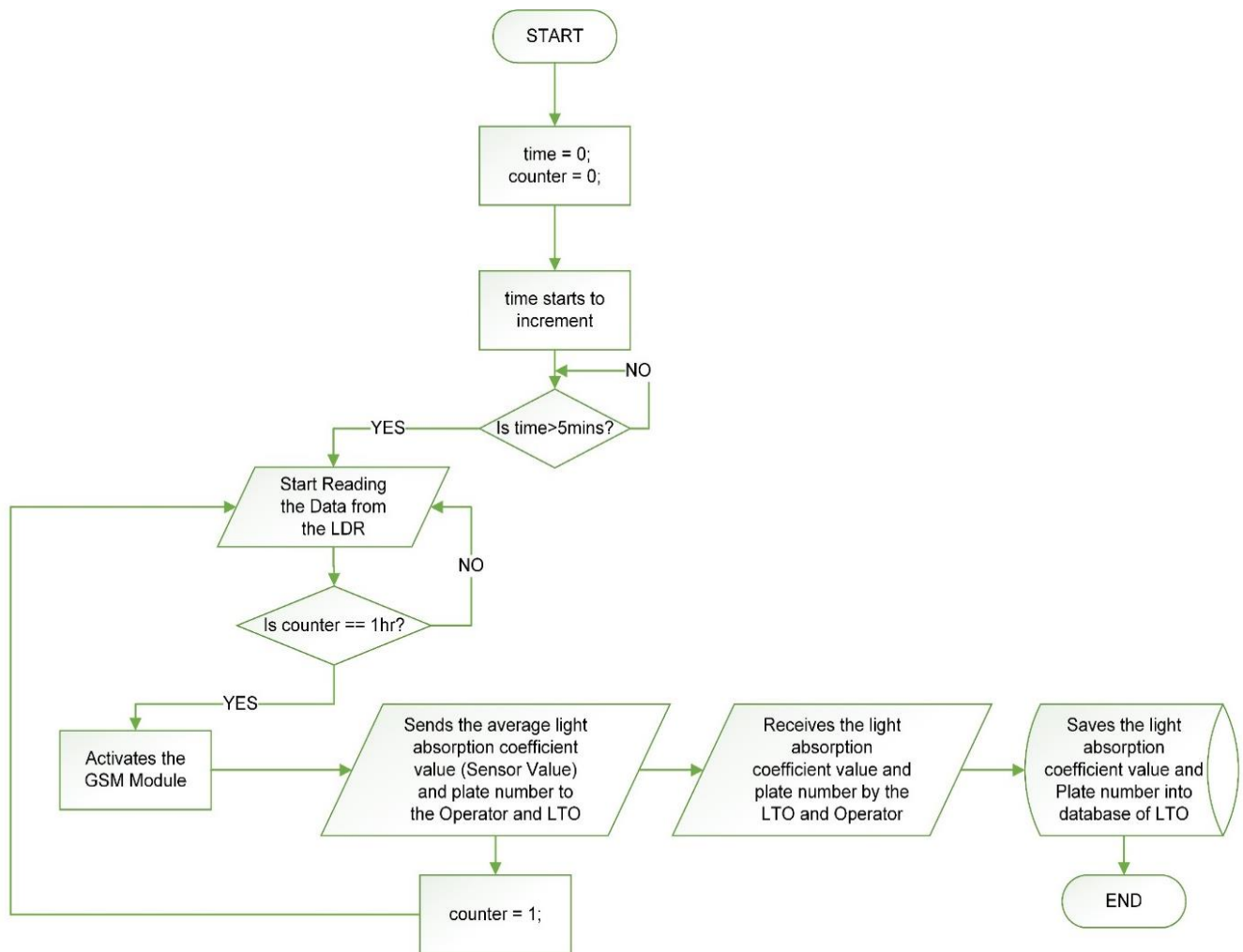$$\alpha = \mathbf{[log\ (Rx/Ro)]\ /x.}$$

Figure 1: System Flowchart

The system starts by incrementing the time in seconds. When the time reaches five (5) minutes, it started reading/measuring the data from the light dependent resistor (every second). The GSM module activates every time it reaches 60 minutes and sends the average light absorption coefficient value and plate number to the mobile phone of the operator/driver and to the database server. The database server receives the value and save it to the database.

The researchers conducted the following processes: (1) Project Planning, (2) Research& Data Gathering, (3) Prototyping, (4) Designing and Constructing of Hardware, (5) Designing and Developing of Software , and (6) System Testing in order to develop a Real-Times Smoke Belching Monitoring System for Public Utility Vehicles. The researcher identified the feedback and repeated the process to attain the desired accuracy of the project.

The researcher used experimental research design to determine the comparison of the conventional way of emission testing to the prototype of the researcher.

This paper aims to develop a monitoring system of smoke belching powered by microcontroller and Global System for Mobile (GSM) to monitor and record the measured light absorption coefficient of any Public Utility Vehicles (PUV).

STATEMENT OF THE PROBLEM

Specifically, the researchers ought to answer the following questions:
1. What opacity meter could be designed and develop to monitor smoke belching through measuring the light absorption coefficient?
2. How reliable is the prototype of the smoke belching monitoring system in terms of:
   2.1 sending and receiving data to the server; and
   2.2 sending and receiving data to the operator's mobile phone.
3 What is the performance of the system in terms of functionality?

METHODS

The participants of this study were the Public Utility Vehicle operators, and drivers who implemented the system. The researcher used purposive sampling to identify the number of the operators and drivers who participated in the evaluation of the system.

The researchers used prototype of an opacity meter connected to an Arduino ATMega 644

microcontroller and Gizduino Global System for Mobile (GSM) shield. This hardware device detects the opaqueness of the smoke (maximum of 2.50 light absorption coefficient) produced by the exhaust of any public utility vehicle. The opacity meter is composed of a Light Dependent Resistor (LDR) and a Light Emitted Diode (LED). The prototype is connected to database software that will record the plate number and the measured light absorption coefficient of a particular public utility vehicle. The system tells when the vehicle is smoke belching. The researchers used different software like Arduino Integrated Development Environment that reads C++ Language, XAMPP Platform for the database and Visual Basic.Net for the Graphical User Interface of the system.

The researchers allowed them to use the prototype to measure the opacity of smoke emitted by the vehicles. The PUV was also tested on the emission testing center to compare the results between the prototype and the accredited testing centers of the LTO. The result of the test was based on the required light absorption coefficient measured (K = 2.50).

The researchers also tested the reliability of the microcontroller and GSM. After reading the light absorption coefficient value, the microcontroller together with the GSM sends the plate number and the measured value to the operator's/driver's mobile phone. The result is also sent to the database software of the system then recorded the data sent by the prototype and measured the time lapse from sending to receiving of data. The researcher conducted first a trial to assure the compliance of the prototype with the task instructions.

The researchers used descriptive statistics. Mean was used to analyze the value of the light absorption coefficient. Standard deviation was used to know the variance of the light absorption coefficient.

RESULTS

Opacity Meter Design and Development

The researchers found that the materials needed in the system were all locally available. The opacity meter measured the quantity of light that badges through the exhaust and determined the duskiness or opacity of the smoke. The software used in the system was user-friendly and could monitor the plate number and the light absorption coefficient of each plate number registered in the system. During the

development of the project, the researcher realized that the dust might affect the light source and the LDR sensor. Also the light source must have a strong light and the light must be directed to the LDR sensor for better reading.

Reliability of the Prototype of the Smoke Belching Monitoring System

It was evident in the findings that sending and receiving light absorption coefficient value was reliable. The table revealed that the delay of the data was due only to the status of the signal of the network. The researcher found out that certain factors might affect the transmission of the information from one GSM (Jeepney) to the other (LTO).

Table 1: Reliability of the System in Receiving of the Plate Number and K-value for Operator via Text Message

Trials (minute)	Light absorption coefficient (LDR sensor value)	Date received	Time received	Delay (minute)
1	0.39 k	Feb. 17, 2015	2:25 pm	0
2	0.40 k	Feb. 17, 2015	2:26 pm	0
3	0.52 k	Feb. 17, 2015	2:28 pm	1
4	0.54 k	Feb. 17, 2015	2:29 pm	0
5	0.49 k	Feb. 17, 2015	2:30 pm	0
6	0.30 k	Feb. 17, 2015	2:32 pm	1
7	0.31 k	Feb. 17, 2015	2:33 pm	0
8	0.28 k	Feb. 17, 2015	2:34 pm	0
9	0.34 k	Feb. 17, 2015	2:36 pm	1
10	0.34 k	Feb. 17, 2015	2:37 pm	0

The researchers noticed that there were slight delays (about 6 to 17 seconds) in terms of texting the information (Plate Number and Light Absorption Coefficient) from both the operator's phone and the program created mainly because of the consideration

of the signal, the GSM's antenna position and the nature characteristic of the GSM itself. As for catching the data via the program that has been created in Visual Basic, the delay took only around 5 seconds to output the texted information.

Performance of the System

Comparative testing with LTO Emission Testing Center showed that the status of the test in the emission center is the same as the status of the test using the prototype. The plate number and the mobile number of the operator/driver of a particular Public Utility Vehicles (PUJ) were embedded to the program of the microcontroller for security purposes. Only the administration that disseminates the utility model is allowed to embed the plate number. The Land Transportation Office (LTO)'s system has a feature that can add or register new jeepneys that will undergo emission testing. The software of the database system has a feature of "log-in and password" for security purposes. It is only the administrator who can administer the software system in monitoring the plate number and the result of the opacity meter sent by the microcontroller-based opacity meter. The Land Transportation Office (LTO) can view all the registered jeepneys and the emission result through the use of localhost database.

Table 2: Emission Testing Center (X) vs Prototype

Diesel Vehicles	Remarks	
	Emission Testing Center	Prototype
Public Utility Jeepney	Passed	Passed
Public Utility Jeepney	Passed	Passed
Public Utility Bus	Passed	Passed
L300	Failed	Failed
Starex	Passed	Passed
Public Utility Jeepney	Failed	Failed

CONCLUSION AND FUTURE WORK

The Development of Real-Time Smoke Belching Monitoring System for Public Utility Vehicles can monitor smoke belching through measuring light absorption coefficient. The system consists of Opacity meter that will measure the quantity of light that badges through the exhaust and determined the duskiness or opacity of the smoke. The duskiness or opacity of the smoke can be determined by the light absorption coefficient by using of Light Dependent

Resistor (LDR) and Light Emitted Diode (LED) found in the opacity meter.

After a series of test conducted in the system in terms of sending and receiving of data it is found out that the system is reliable. The reliability of the whole project is comparable to the standard opacity meter. The system could directly and in real-time monitor the PUV tested as smoke belching.

Functionality of the system is very evident. Comparative testing with LTO Emission Testing Center showed that the status of the test in the emission center is the same as the status of the test using the prototype.

The working temperature of the LDR is only at 60 degree Celsius below. The sensor is more sensitive in moist and wet environment. This research focused only in monitoring public utility vehicles which use diesel that emit an amount of density or opaqueness of the smoke. The researcher did not cover other chemicals and compound elements present in smoke belching emissions.

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