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Development of Diesel Vehicular Pollution Monitoring Equipment

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ABSTRACT

The purpose of this study was the development of microcontroller based low cost environmental pollution monitoring equipment to measure smoke densities of Diesel Vehicles. The Equipment consisted of two parts namely, emission probe and the processing unit. Light Dependant Resistor(LDR) and white colour Light Emitting Diode(LED) are placed on either side by perpendicular to the emission flow of the probe. LDR is used as the emission detector and white colour LED used as the light emitter. An analog to digital conversion for the PIC 16F877A microcontroller was used in the processing unit. Each test value was compared with its smoke absorption density, which detected from the standard instrument at the same time. Instrumental error of smoke absorption density for developed instrument is ± 0.007 m^{-1}.

1. INTRODUCTION

Pollution is the introduction of contaminants into an environment that causes instability, that mean cause disorder, harm or discomfort to the humans or other living organisms, or damages to the natural environment [1].The elements of pollution called Pollutants can be foreign substances, energies or naturally occurred contaminants exceeding acceptable natural levels. The major forms of pollution are air pollution, light pollution, littering, noise pollution, soil contamination, radioactive contamination, thermal pollution, visual pollution and water pollution.

Air pollution is one of the common problems faced by rapidly expanding metropolitan environment. It is created by humans by adding chemicals, particular matters and biological materials into the environment [2]. Common air pollutants include carbon monoxide, sulphur dioxide, chlorofluorocarbons (CFCs) and nitrogen oxides produced by industry and motor vehicles [3]. Particulate matter or fine dust is characterized by their micrometer size PM_{10} to $PM_{2.5}$.

There are three ways of generating Vehicular Emissions namely, from Crank case, from Fuel System and from Exhaust [4]. These emissions cause sometimes deaths and respiratory related problems in humans as well as in other living organisms. Many countries have policies to control vehicular emissions. With the Kyoto Protocol came into effect in 2005, member countries have been forced to reduce gas emissions by 2012. As a result, the Ministry of Environment and Natural Resources has taken strong measures to control pollution caused due to vehicular emissions. At present, all motor vehicles in Sri Lanka would require to obtain exhaust emission report for the renewal of revenue license.

There are various techniques to monitor air pollutants of CO_2, CO, SO_2, NO_X, CH_4 and particular matter of which can be detected either using chemical or solid state sensors

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[5]. This paper discusses about development of a microcontroller based, low cost diesel vehicular pollution monitoring equipment.

2. DESIGN AND CONSTRUCTION

Equipment was developed to test smoke density of Diesel Vehicles. It consists of two parts. One is emission probe and other one is the processing unit (Figure 1). Emission flow was going through the probe. Light Dependant Resistor (LDR) and white colour Light Emitting Diode (LED) were placed on either side perpendicular to the flow. LDR is used as the emission detector when the white LED is used as the light emitter.

Analog to digital conversion of PIC 16F877A is used to develop the instrument. Express PCB software is used to draw the layout of the circuit (Figure 3). Figure 4 shows the internal view of the circuit. In the process of testing, emission probe is entered into the exhaust tube of the vehicle (Figure 5). The display panel shows the emission level from the range of 0.000 – 10.000 (Figure 6).

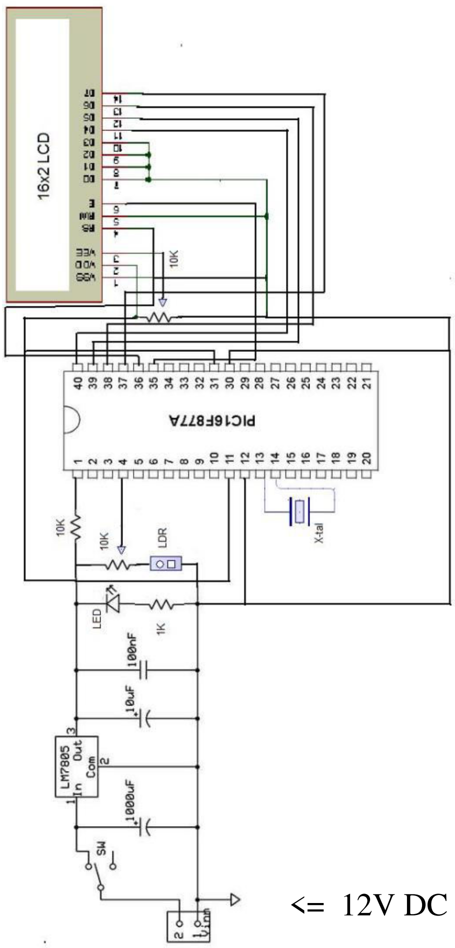

Figure 1: Schematic diagram of the circuit

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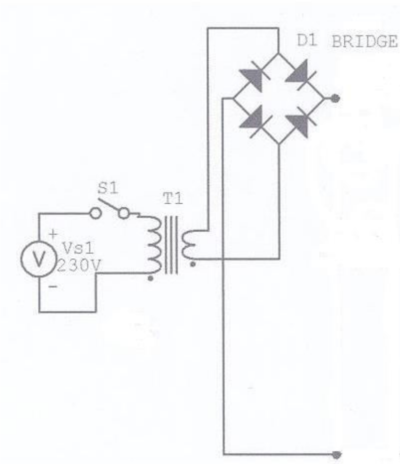

T1 - 230V to 12V AC, 1A step down transformer
S1 - Power on / off switch
D1 - 1N4001 Rectifier Bridge

Figure 2: 12V DC power supply unit for the circuit

12V DC voltage was supplied to the circuit (Figure 2). LM 7805, voltage regulator converted 12V DC voltage to 5V DC voltage. Two capacitors of 1000 µF and 10 µF used to smooth the DC current, which supplied to PIC microcontroller. 10 nF capacitor used to block noise and unwanted signals in the power supply. 10 KΩ variable resistors can adjust the zero point of the display smoothly. 5 MHz Cristal (X-tal) used to get clock pulse for PIC microcontroller. 16 x 2 Liquid Cristal Display(LCD) was the display panel.

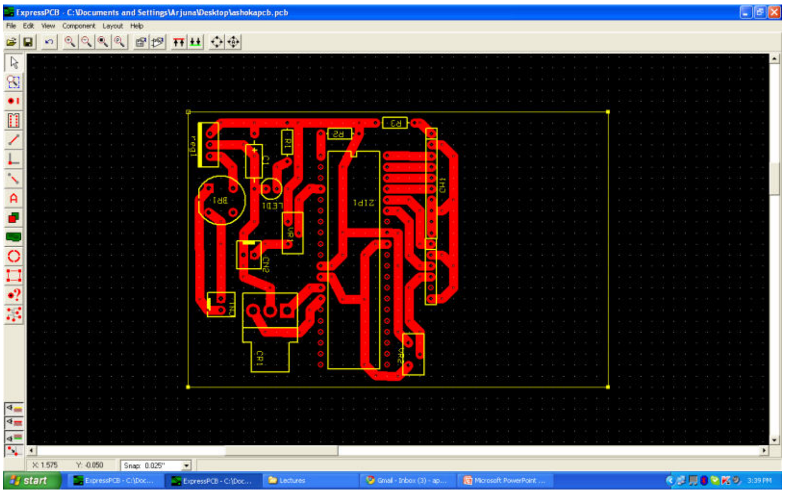

Figure 3: Express PCB software layout of the circuit

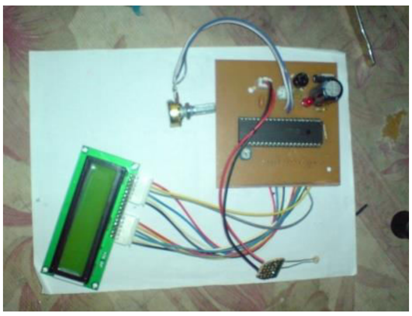

Figure 4: Internal view of the instrument

Figure 5: External View of the instrument

Figure 6: Display panel of the Instrument

Testing of the diesel vehicular emissions was carried out in Mirihana area at the Emission testing and engineering centre of Cleanco Lanka (Pvt.) Ltd. Vehicles were tested with this emission detector parallel to their testing scheme for two weeks duration. Buses, light land vehicles, motor cycles, motor tricycles and prime movers were significantly low, below 10 on this period. So, these values weren't taken to the calculations. Test values of the developed instrument and its Smoke absorption densities (K) of the testing certificate issued by the centre for each vehicle were observed. Vehicles within the pass limit were considered only to obtain a pattern of the developed Instrument.

3. RESULTS AND DISCUSSION

3.1 Calibration of the Instrument

Light absorption (Opacity) follows the Beer-Lambert Law [6],
Opacity (%) = $100\,(1 - e^{-KL})$
Where,

K = Smoke absorption density (m^{-1})
L = Path length of light through the smoke (m)

Without any smoke through the detector, Opacity (%) $\rightarrow 0$ when $K \rightarrow 0$,
In the highest smoke level, Opacity (%) $\rightarrow 100$ when $K \rightarrow \infty$

Opacity (%) Smoke absorption density (m^{-1})

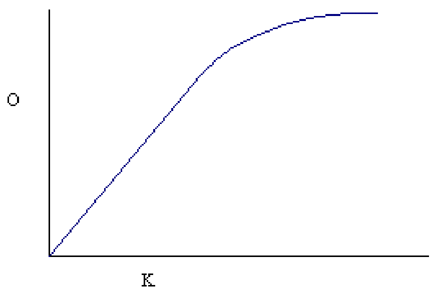

Figure 7: Opacity (O) vs Smoke absorption density (K) graph

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According to Figure 7, the linear relationship between the Smoke absorption density and the Opacity is used to develop the Smoke density measuring equipment.

The Instrument was calibrated against the Standard glasses of known smoke absorption densities (K). Displayed values of the instrument for known K values were in Table 01.

Table 01: Instrument Readings with K values

K (m^{-1})	Instrument Reading
0.00 (without block)	0.000
1.68	0.051
1.88	0.059
2.20	0.071
2.93	0.091
∞ (full block)	9.960

Reading of the Instrument for Full block status (K = ∞) hasn't taken to plot the graph. Because (9.960, ∞) point isn't behave in the linear stage of the K vs Opacity curve.

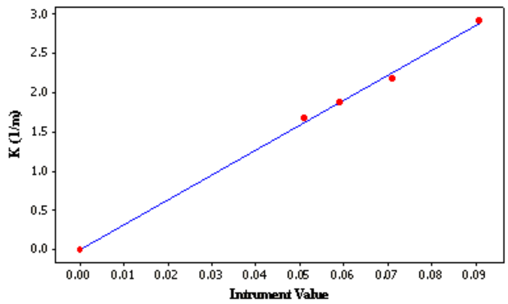

Figure 8: Regression graph for the calibration of instrument

The regression equation for the Calibration graph of Figure 8 is,

$$K = 0.006 + 31.8 *(\text{Instrument value})$$

3.2 Regression Equation for the Average Emission Density of Diesel Vehicles

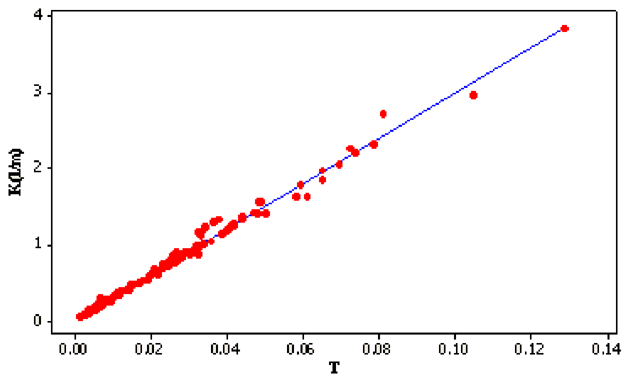

Figure 9: K vs T Graph for average diesel vehicles

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The regression equation for the graph in Figure 9 is,

$$K = 0.012 + 29.8\ T$$

Carefully examining the above graph, when the displayed value has below 0.06, the Instrument can get good results.

It is assumed that the vehicles, which passed the emission test have behaved in the linear equation of $K = 0.012 + 29.8\ T$.

Two conditions were applied in the test certificate to pass the emission test.

1. Average Smoke Density (K) shouldn't exceed the $K= 8\ m^{-1}$ limit
2. The difference between the highest and the lowest Smoke Densities of three snap accelerations shouldn't exceed $1\ m^{-1}$

For the condition 1, applying $K= 8\ m^{-1}$into the above equation,

$T = (8 - 0.012) / 29.8$
$T = 0.268$
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For the condition 2,
Considering the highest value of $K = K_1$, related to $T = T_1$ and the lowest value of $K = K_2$related to $T = T_2$,

Applying (K_1, T_1) and (K_2, T_2) into the $K = 0.012 + 29.8\ T$ equation,

$T_1 - T_2 = (K_1 - K_2) / 29.8$
For the pass status, $K_1 - K_2 \leq 1\ m^{-1}$

So, $T_1 - T_2 \leq 0.336$

Considering above conditions, new condition can be built to check the pass status of the emission test with developed Instrument.

1. Test values of the Instrument shouldn't exceed the 0.268 value
2. The difference between the highest and the lowest Instrument values of three snap accelerations shouldn't exceed 0.336 value

3.3 Error Calculation of the Instrument

Instrument value (T) vs Smoke absorption density of the standard instrument (K) graph was considered for the error calculation of the developed instrument.

Instrument value(T) vs Smoke absorption density(K)

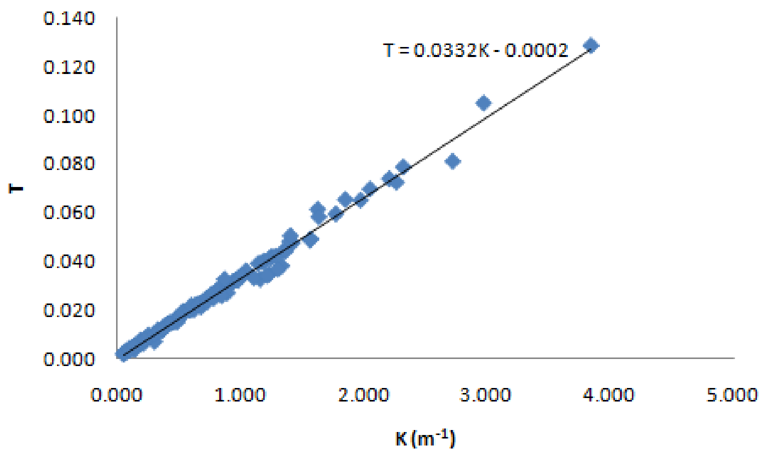

Figure 10: T vs K Graph of Average Diesel Vehicles for error calculation

- For the standard instrument
  Standard deviation of K; (σ_1)= 0.647 m^{-1}

- For the behaviour pattern of the T vs K graph (Figure 10)
  Calculated Standard deviation against standard K value; (σ_2) = 0.654 m^{-1}

Instrumental error of Smoke absorption density $= \sigma_2 - \sigma_1$

$= \pm 0.007\ m^{-1}$

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4. CONCLUTION

The emission detecting instrument developed, found to function more accurately below of 0.06 level or K = 1.8 m^{-1}, which was calculated according to the linear equation of K = 0.012 + 29.8 T.

Sometimes, as the instrument was switched on after certain period, it didn't display anything on the display panel. When 12V DC supply was produced to the circuit through the power supply unit, it couldn't get smooth voltage practically. DC supply has some attenuation. At that time the display panel wasn't activated. This error could be minimized by switching on the Instrument after waiting for few minutes to discharge Capacitors.

Using the Instrument for longer periods or expose to smoke with high densities, some pollutant particles can be deposited on the LED and LDR. Before using the instrument for testing, those surfaces should have cleaned with a paper tissue or with a smooth piece of cloth. Some unusual deviations over the 0.06 point of the Instrument value were due to the high concentrated carbon particles passed through with the smoke.

For future developments, some solutions should be found out to clean the emission probe, which containing LED and LDR and high concentrated carbon particles flowing

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without any continuity. In this regard,LED and LDR can be replaced by more accurate sensors like Non Dispersive Infrared(NDIR) sensors.

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