Accuracy Improvement of PM Measuring Instruments

Tae-In Hyon¹, Gyu-Sik Kim²

¹Linc Industry, University Cooperation Group, Jeonju University, Jeonju, Korea
²Department of Electrical and Computer Engineering, University of Seoul, Seoul, Korea

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ABSTRACT

The PM₁₀ concentration in the underground areas should be monitored to protect the health of the commuters in the underground subway system. The purpose of this work is to study the reliability of the instruments using light scattering method to measure the PM₁₀ concentrations continuously. A linear regression analysis method is used to improve the performance of the instruments using light scattering method. Some experimental results show that a linear regression technique would be very helpful for the performance improvement of light scattering instruments such as Airtest PM2500 and HCT 4103.

KEYWORDS: PM10, underground subway system, light scattering method, linear regression analysis

I. INTRODUCTION

Particulate matter with an aerodynamic diameter less than 10 μm (PM₁₀) is one of the major pollutants in subway environments. The PM₁₀ concentration in the underground areas should be monitored to protect the health of the commuters in the underground subway system [1-9]. Seoul Metro and Seoul Metropolitan Rapid Transit Corporation measure several air pollutants regularly. As for the PM₁₀ concentration, generally, measuring instruments based on β-ray absorption method are used.

In order to keep the PM₁₀ concentration below a healthy limit, the air quality in the underground platform and tunnels should be monitored and controlled continuously. The PM₁₀ instruments using light scattering method can measure the PM₁₀ concentration every once in several seconds. However, the reliability of the instruments using light scattering method has still not been proven since they measure the particle number concentration rather than the mass concentration [10].

The purpose of this work is to study the reliability of the instruments using light scattering method to measure the PM₁₀ concentrations continuously in the underground subway stations. A linear regression analysis method is used to improve the performance of the instruments using light scattering method. The data measured by these instruments have to be converted to actual PM₁₀ concentrations using some factors. These findings propose that the instruments using light scattering method can be used to measure and control the PM₁₀ concentrations of the underground subway stations.

II. Measurement of Particulate Matter

2.1 Airtest PM2500 laser particulate monitor:

Airtest PM2500 which is shown in Fig. 1 is a two-channel laser particulate meter that displays the average counter of particles of 1 to 5 micron each minute and larger than 5 micron. One can change several options with the front buttons. The characteristics of Airtest PM2500 laser particulate monitor is summarized as follows:

- Designed for use in homes or offices.
The general specifications of Airstest PM2500 laser particulate monitor is summarized as follows:

- **Sampling method**: Laser particle counter. This device is a Class 1 laser product and complies with 21 CFR 1040.10 and 1040.11.
- **Particle channels**: 1.0-5.0 μm, 5.0+ μm
- **Flow rate**: 0.06 cfm nominal
- **Concentration limit**: Coincidence loss less than 10% at 1,000,000 particles/cubic foot
- **Display format**: Particles/cubic foot (divided by 100) averaged over 1 minute
- **Data storage**: 60 minutes of minute averages, 24 hours of hourly averages, 30 day of daily averages
- **Dimensions**: 7.5 x 5.0 x 3.5 inches
- **Weight**: approximately 12 oz
- **Power**: 9VDC, 400mA, 110VAC plug-in transformer provided.

**2.2 HCT 4103 particle sensor**

HCT 4103 particle sensor is shown in Fig. 2.

![Fig.2. HCT 4103 particle sensor](image)

A light scattering particle sensor provides an extremely sensitive tool for the measurement of aerosol concentration and particle size. HCT Particle Sensor model 4103 can provide instantaneous and continuous particle monitoring information. The characteristics of HCT 4103 particle sensor is summarized as follows:

- Compact, convenient, light weight
- Sizing sensibilities from 0.3 ~ 10 μm
- Easy to install in narrow space
- Smooth, durable exterior design
- Real time data display
- Easy system interface
- Compliant with JIS standards

The general specifications of HCT 4103 particle sensor is summarized as follows:

- **Size range**: 0.3 ~ 10 μm
- **Flow rate**: 0.1 CFM (2.83 L/min)
- **Counting efficiency**: 50% @ 0.3 μm, 100% for particles > 0.45 μm (meets JIS)
- **Laser source**: Laser diode
- **Zero count level**: < 1 count / 5 minutes (meets JIS)
- **Vacuum requirements**: External vacuum
- **Maximum particle concentration**: 5,000,000 particles/ft³
- **Front panel display**: LCD panel
- **Output interface**: RS422
- **Dimensions (LWH)**: 84 X 105 X 60 mm
- **Weight**: 0.5 kg

**2.3 Linear regression analysis**

Generally, a linear regression straight line is expressed as eq (1).

\[ y = \hat{m}x + \hat{b} \]  

(1)

In order to find the unknown variables \( \hat{m} \) and \( \hat{b} \) which minimize the error \( e \), the partial differentiations are used as

\[ \frac{\partial e}{\partial \hat{m}} = -2 \sum_{i=1}^{N} x_i (y_i - (\hat{m} x_i + \hat{b})) = 0 \]  

(3)

\[ \frac{\partial e}{\partial \hat{b}} = -2 \sum_{i=1}^{N} (y_i - (\hat{m} x_i + \hat{b})) = 0 \]  

(4)

From eq (3), we can get eq (4).

\[ \hat{m} \sum_{i=1}^{N} x_i^2 + \hat{b} \sum_{i=1}^{N} x_i = \sum_{i=1}^{N} x_i y_i \]  

(4)

Eq (5) can be obtained using eq (4).

\[ \hat{m} = \frac{N \sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N \sum_{i=1}^{N} x_i^2 - (\sum_{i=1}^{N} x_i)^2} \]  

(5)

\[ \hat{b} = \frac{1}{N} \left( \sum_{i=1}^{N} y_i - \hat{m} \sum_{i=1}^{N} x_i \right) \]

**2.4 Application of linear regression analysis**

The PM measuring instruments Airstest PM2500 and HCT 4103 were installed at a subway station for 480 minutes as shown in Fig. 4. The PM_{10} measurement data of Airstest PM2500 and HCT 4103 are shown in Fig. 5. Using the linear regression analysis technique, the measured PM_{10} concentration of Airstest PM2500 in Fig. 5 can be corrected as shown in Fig. 6. The PM_{2.5} measurement data of Airstest PM2500 and HCT 4103 are shown in Fig. 7. Using the linear regression analysis technique, the measured PM_{2.5} concentration of Airstest PM2500 in Fig. 6 can be corrected as shown in Fig. 8. It can also be seen in Fig. 6 and Fig. 8 that the measurement data of Airstest PM2500 was closely similar as those of HCT 4103 if they were corrected using a linear regression technique. So, it can be concluded that a linear regression technique would be very helpful for the performance improvement of light scattering instruments such as Airstest PM2500 and HCT 4103.
III. Concluding Remarks

The metropolitan city of Seoul uses more energy than any other area in South Korea due to its high population density. It also has high emissions of air pollutants. Since an individual usually spends most of his/her working hours indoors, the ambient air quality refers to indoor air quality. In particular, PM$_{10}$ concentration in the underground areas should be monitored to preserve the health of commuters in the subway system. Through some experimental studies, we found that a linear regression technique would be very helpful for the performance improvement of light scattering instruments such as Airtest PM2500 and HCT 4103. These findings propose that the instruments using light scattering method can be used to measure and control the PM$_{10}$ concentrations of the underground subway stations.

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References


