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MEASUREMENT OF DUST MASS CONCENTRATION

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Abstract: The paper deals with measurement of dust mass concentration in working environment. Because of variability of the quantity, also uncertainty balance is needed. There are several methods for measurement of dust mass concentration. Gravimetric methods is frequently used for this purpose, but also this method is used as reference methods for calibration of others methods of measurement.

1 Introduction

Dust mass concentration is a quantity measured in working environment and also in country environment. The dust mass concentration in country environment is increased in last years. It is related to pollutants producet by factories, cars, coal heating and other human activities.

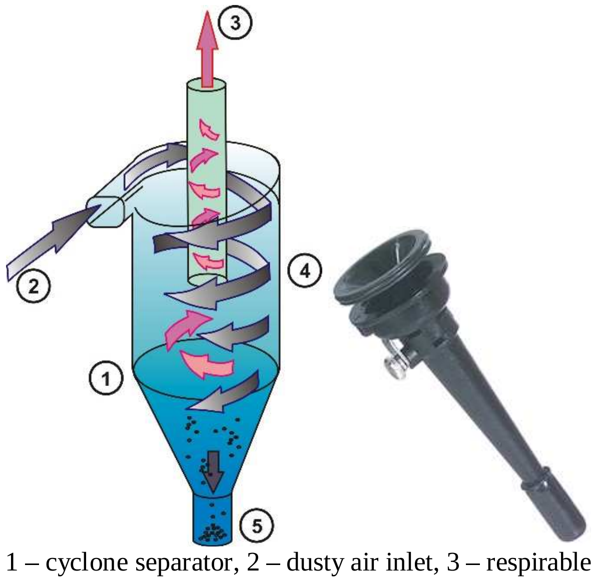
Working environment is mainly sensed inside buildings. There are defined linits for the values of dust muss concentration for working environment.

Pollutant emmision is very strictly monitored parameter of air quality.

Dust is very dangerous for human helathy and life. From hygienic viewpoint, the dust is defined as small particles of solid state materials, which are dispersed in environment air otherwise which are sedimentary on various objects. These particles come from the various technological operations (metallurgical technological operations, combustion of various substances, ore-working industry, threadmills, cement industry, cereals cleaning, processing of dry vegetal materials, wood processing etc.).

For practical purposes it is possible to divide dust particles into these categories – dimensional fractions: respirable and non-respirable dust fraction. The main goal of this dividing is to imitate the dust separation of the human breathing. So, respirable fraction is the part of dust particles, which is possible to respirable inside the human breathing ways.

Respirable dust transducer would by a sensitive only to respirable dust fraction. This requirement is achieved in practise with using of pre-separator. The most used pre-separator is so-called cyclone, which uses the mechanical way of the dust separation. A cyclone (fig. 1) is a size-selective device used to separate respirable and non-respirable-sized particles from the air. The name „cyclone“ is coming from their principle, which is based on high velocity airflow rotating inside cyclone and separating the particles with high aerodynamics diameter. The small particles pass thorough the cyclone and they are collected on filter material [1-17].



1 – cyclone separator, 2 – dusty air inlet, 3 – respirable dust air outlet, 4 – airflow path, 5 – non-respirable dust fraction
Figure 1 separation of non-respirable dust fraction [18]

Dust laden gas enters the chamber from a tangential direction at the outer wall of the device, forming a vortex as it swirls within the chamber. The larger articulates, because of their greater inertia, move outward and are forced against the chamber wall. Slowed by friction with the wall surface, they then slide down the wall into a conical dust hopper at the bottom of the cyclone. The

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cleaned air together with respirable dust fraction swirls upward in a narrower spiral through an inner cylinder and emerges from an outlet at the top. Accumulated non-respirable particulate dust is deposited into a hopper, dust bin or screw conveyor at the base of the collector.

The cyclone is made from electrostatic conductive material (aluminium or conductive plastic), which is needed for elimination of electrostatic phenomena which occurs in nylon cyclone.

There is also a different way how to separate dust. For optical measurement method it is possible via "non-mechanical way". One of the possible ways is based on suitable wavelength of light radiation and scatter angle. Another possible non-mechanical way is based on suitable signal processing from light scattering sensor [1-17].

The main goal of this paper is to show the possibility of change of the mechanical pre-separators with suppressing of the dust transducer sensitivity to non-respirable dust fraction based on signal processing for light scattering dust transducer. This way represents one of the possible approaches to the problem solving, which is oriented to replacement of the mechanical parts with electronics or signal processing for obtaining of the overall properties improvement of the function, which has been provided via mechanical part.

2 Gravimetric method for dust mass concentration measurement in working air environment

The gravimetric method principle (fig. 2) lies on fact, that dust sample from air is captured on suitable type of the filter.

Weight difference of the filter before and after sampling and airflow velocity is basic information for dust mass concentration Mc identification. It can be obtained from equation (1):

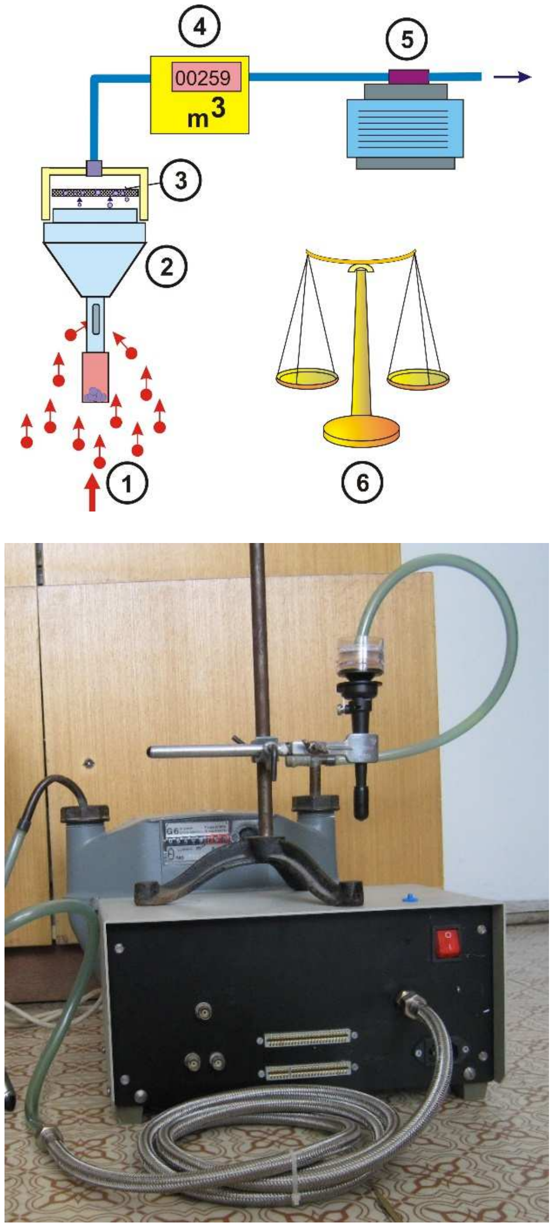
$$M_C = \frac{m_{before} - m_{after}}{Q_V} \tag{1}$$

where: m_{before}, m_{after} – are filter weights before and after sampling,

Q_V – volume airflow velocity,

The main advantage of the gravimetric method is simplicity and comparable results independent on used measuring devices. So, the gravimetric method has been accepted as reference method for dust mass concentration measurement [19].

Filter is made from cellulose, glass fibre, teflon, MCE – mixed cellulose ester, PVC, silver etc. Measurement range with this method is 0.1-2000mg/m3 (it depends on device producer) [19].



1 – dusty air, 2 – cyclone, 3 – filter, 4 –volume flowmeter, 5 – high-volume pump, 6 – analytic scales

Figure 2 Principle of dust mass concentration measurement with gravimetric method [19]

3 Uncertainty of measurement of dust mass concentration

Standard uncertainty of measurement of dust mass concentration can be described as (2):

$$u_{Mc} = \sqrt{\left(\frac{\partial M_C}{\partial m_{after}}\right)^2 \cdot u^2_{mafter} + \left(\frac{\partial M_C}{\partial m_{before}}\right)^2 \cdot u^2_{mbefore} + \left(\frac{\partial M_C}{\partial Q_V}\right)^2 \cdot u^2_{Qv}} \tag{2}$$

where: m_{before}, m_{after} – are filter weights before and after sampling; Q_V – volume of sampled polluted air; umafter, umbefore – are standard uncertainty of measurement of filter weight before and after sampling; u_{Qv} – is standard uncertainty of measurement of volume of sampled polluted air.

Partial sensitivities can be derived as follow (3):

$$\frac{\partial M_C}{\partial m_{after}} = \frac{1}{Q_V};\ \frac{\partial M_C}{\partial m_{before}} = -\frac{1}{Q_V};$$
$$\frac{\partial M_C}{\partial Q_V} = -\frac{1}{Q_V^2}\left(m_{after} - m_{before}\right). \tag{3}$$

After substitution of partial sensitivities into equation 2 (4):

$$u_{Mc} = \sqrt{\left(\frac{1}{Q_V}\right)^2 \cdot u^2_{mbefore} + \left(-\frac{1}{Q_V}\right)^2 \cdot u^2_{mafter} + \left(-\frac{1}{Q_V}\cdot\left(m_{after} - m_{before}\right)\right)^2 \cdot u^2_{Qv}} \tag{4}$$

Uncertainty of both weight measurements are equal $u_{mbefore}=u_{mafter}=u_m$, so it is possible write equation for standard uncertainty of dust mass concentration (5):

$$u_{Mc} = \frac{1}{Q_V}\sqrt{2\cdot u_m^2 + \left(m_{after} - m_{before}\right)^2 \cdot u^2_{Qv}}. \tag{5}$$

Standard uncertainty um and u_{Qv} should be as combined standard uncertainties which consist of standard uncertainty obtained via using of method A and via using of method B. Conditions are not fulfilled for obtaining of standard uncertainty obtained via using of method A. Consequently, standard uncertainty um and u_{Qv} are equal directly to standard uncertainties obtained via using of method B (it means from datasheet supplied by producer).

4 Calibration of dust mass concentration measurement devices

Standard VDI2206 deals with calibration of dust monitors. Calibration based on this standard assigns the values of dust mass concentration to the measured values of output quantity from dust monitor (e.g. intensity of scattered light). The most frequently used methods is comparative measurements directly on explored place exposed to dust emmision.

Practical realistaion of calibration depends on many factors as working conditions, optical and physical properties of dust, condition of sampling of air contamined with dust. All these factors should be respected also during the calibration process. Because of these reasons, calibration requires large attention. All condition during calibration has to be noted for later analysis. The mentioned standard recommends the minimally 15 comparative measurement for reliably execution of calibration process. Time of one measurement should be less then 30 minutes.

5 Conclusion

Final standard uncertainty depends on calibration process. Also previous experiences show signification of calibration process. Dust mass measurement is very specific type of measurement, because of their variability. This variability is caused by production process, which is as source of dust pollutant emissions etc. Consequently, calibration process has to be executed directly on measured place and it is necessary to repeat it very frequently (mainly in case of changed production conditions). This paper also shows that calibration is very significant for determination of uncertainty of measurement and shows the way how it is possible to minimize the uncertainty of measurement [6-39].

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