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Remarks about calibration of Automatic Analyser of Aerosols

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The working principles of the instrument, called Automatic Analyser of Aerosols (AAA), are presented in the paper. Certain problems arising during calibration and being important in the interpretation of the measurements are discussed.

1. Introduction

The basic problem of aerosol study is the measurement of particles characteristics and determination of particles size distribution parameters or the distribution itself. The latter is possible practically only by single-particle measurements. The methods of the greatest interest involve light scattering techniques and provide the opportunity of non-destructive measurements in situ. Calculations as well as experimental studies on the subject have shown that special attention should be given to scattering. The response curve in forward region is practically insensitive to the refractive index of the material of particle and to certain extent to its shape and can yield unambigous values of its size.

2. Experiment

On the basis of the above remarks an apparatus for the measurements of sizes of particles was constructed [1]. Its scheme is presented in Fig. 1. The formation of the laser beam is applied in order to obtain high intensity homogeneous illumination of the particles. Intensity distributions in the cross-section of the beam along the optical axis are presented in Fig. 1. Unscattered light passes through the hole in the mirror onto the photodiode used for the intensity control. Lateral maxima of Fresnel diffraction on the first slot are cut off by the second one. Cylindrical lens focuses the beam onto the measuring volume. Flowing aerosol is formed in a narrow filament by air-sheath nozzle. Single particles move in a protective stream of filtered air which eliminates additional scattering. Scattered light is collected by the system consisting of a lens and a pinhole and detected by a photomultiplier. Arising pulses are amplified in logarithmic amplifier and counted by multichannel hight pulse analyser. Simultaneously, pulses are monitored with oscilloscope providing the control of aerosol concentration. If particles do not pass through the beam of light one by one the need of adjustments is clearly seen.

Measurements of particle dimensions should be preceded by calibration of the apparatus with the particles of a known size distribution. An attention must be payed to a certain problem, often neglected during calibration and

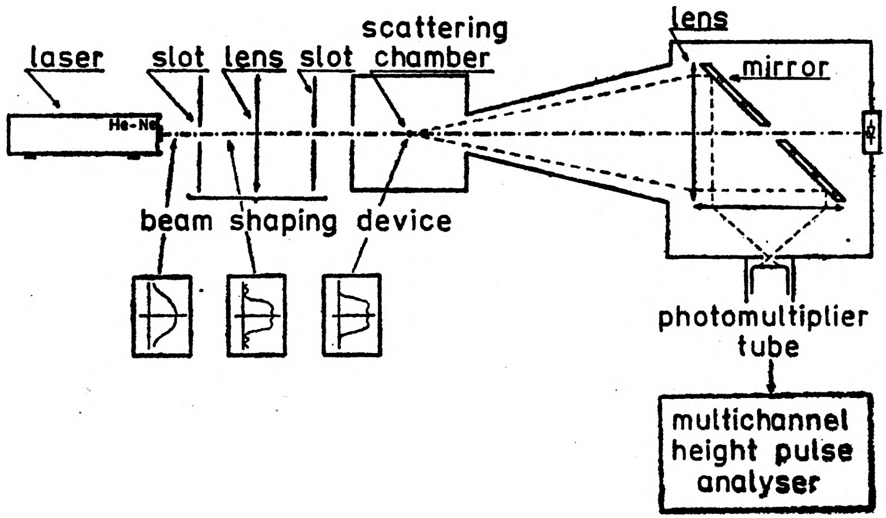

Fig. 1. The schematic representation of the apparatus for measurements of particle sizes, called Automatic Analyser of Aerosols (AAA)

measurements. It concerns all the systems characterized by log-normal distribution. Density function of the probability of random variable distribution, the size of particles, for instance, should be interpreted as:

$$f(d) = \frac{n(d)}{\Delta d},$$

where n is the number of particles of dimensions ranging within the interval $\left(d-\frac{\Delta d}{2},\ d+\frac{\Delta d}{2}\right)$.

If we neglect the problem of definite width Δd then the factor $\Delta d/d$ — weighted width of the interval, can be expressed as follows:

$$\left(\frac{\Delta d}{d}\right) = 2\left(\frac{d_{i+1}}{d_i}-1\right)\Big/\left(\frac{d_{i+1}}{d_i}+1\right),$$

i being the channel number.

Let us assume that in a certain range the intensity of light can be described as:

$$I = A\cdot d^m,\ A \text{ — constant.}$$

Now, if the pulses proportional to the light intensity are logarithmically amplified and

$$U = k\cdot\log(B\cdot I) = k\cdot m\cdot\log(d)+C,\ B,\ C \text{ — constant},$$

where U — amplitude of pulses, then

$$\left(\frac{\Delta d}{d}\right) = 2\left(10^{\frac{\Delta U}{km}}-1\right)\Big/\left(10^{\frac{\Delta U}{km}}+1\right).$$

Factor $\Delta d/d$ will be constant if:

i) the width of the channel ΔU is constant (that is always assured),

ii) exponent m is constant.

If the constancy of $\Delta d/d$ is not warranted then there will occur some errors (the shift of the mean value of distribution and distortion of distribution shape).

Calibration of the apparatus was conducted using melamine particles of the known size distribution. The response of the aerosol analyser is presented in Fig. 2.

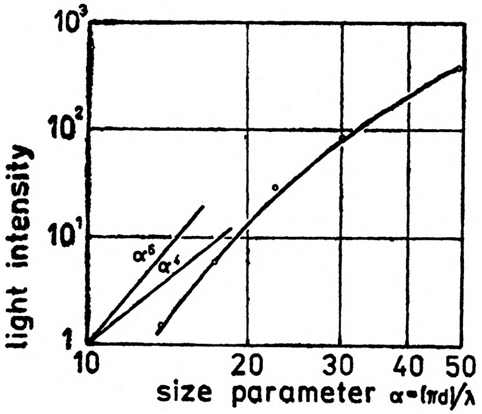

Fig. 2. The intensity of scattered light vs. size parameters a, where d is diameter of particles, λ — length of He-Ne laser light

The slope of the curve is very steep (exponent m varies from 6 to 4). Such a steep dependence leads to high resolving power, but at the same time creates problems with amplification of pulses in very wide range of amplitudes.

The measurements of aerosol distributions in various conditions were conducted with the aid of AAA (the particles were sprayed from suspension). One of the distributions obtained for particles sprayed from suspension is presented in Fig. 3.

Apart from the main maximum there are two other maxima connected with lumps composed of two and three particles (statistical measurements and the control of the counting process exclude the possibility of scattering simultaneously from several single particles passing through the scattering volume). The analysis of the above distribution allows us to formulate the following statements:

1. For the particles of nonspherical shape the cross-section for scattering is connected with the largest dimension of the particles, because of the supposed chaotic rotation of the particle during its passage through the measuring volume.

2. The intensity of light scattered on multiple particles is proportional to their total cross-section.

Information concerning the measurements for the case of particles smaller by one order of magnitude ($d < 2$) show a fourfold increase of the intensity

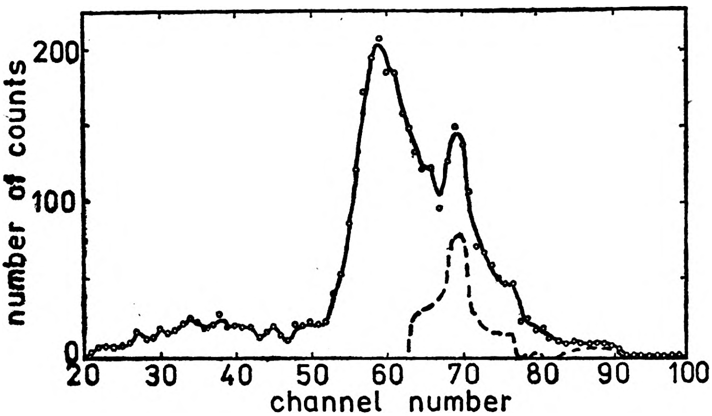

Fig. 3. The example of the distribution curve obtained from the multichannel pulse height analyser

of the light scattered on double particles, in accordance with the model of dipol scattering. For larger particles that model does not hold.

The conducted measurements assured the advantages of using small angle scattered on single particles for determination of distribution of their dimension. They proved to be not so time consuming as stated by certain authors. Amplification by fast amplifier and counting by multichannel pulse height analyser together with the fulfilment of some conditions concerning the geometry of scattering enabled to obtain satisfactory results in the time as short as several seconds.

References

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[2] Van de Hulst H.C., *Light Scattering by Small Particles*, J. Wiley and Sons, New York 1957.

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Замечания о колибровке автоматического анализатора аэрозоля

В статье приведены принципы работы инструмента, называемого автоматическим анализатором аэрозоля. Обсуждены некоторые проблемы, появляющиеся при калибровке, важные для интерпретации измерений.