Development of Surface Particle Counter and its Performance

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Abstract

Particulate contaminants (Size: ca. 10 – 100 μm) can cause quality defects in the products of many industries, such as optical machine assembly and the coating process in car production. There are some methods to evaluate such particulate contaminants that have fallen down from the atmosphere. One of them is exposing a sampling plate and evaluating the surface particle cleanliness (SPC) on it. However, there is no measurement instrument that can be widely applied for various industries, therefore the development of such an instrument has been desired with low cost, easy operation, and short measurement time. We developed a new measurement instrument, Surface Particle Counter which can measure surface particle concentration on a plate. It can be also applicable to ISO/FDIS 14644-9.

According to our evaluation, the counting efficiency is equivalent to the discrete-particle-counting, light scattering instrument. The concentration results measured by our new measurement instrument are also reasonable compared to a conventional microscope method in case the particle concentrations are varied.
The measurement time is about 60 sec which is significantly shorter than the conventional methods. The operation is also very simple and easy.

Our new measuring instrument can replace the conventional methods for the measurement of such particle contaminants in electronics and machinery industries.

Key words: Particulate Contamination, Surface Particle Cleanliness, Measurement Technology, Measuring Instrument, Surface Particle Counter, Metrology.

1. Introduction

In recent years, particulate contaminants around 10 – 100 μm in size that fall down from the atmosphere have become a serious problem in the assembly lines of optical instruments, the coating process of car production and so on. Such particulate contaminants generally fall down from the atmosphere and accumulate in cleanrooms. The accumulated contaminant dirties the surface of image sensors, liquid crystal of projectors and results in the degradation of image quality. The contaminants also affect the surface quality of coating in the automobile industry. It is necessary to monitor quantitatively and control the number of such contaminants from the atmosphere in order to solve such problems.

One of the measurement methods for such contaminants is exposing a sampling plate and predicting from the surface particle cleanliness (SPC) [1)]. The definition of SPC and the measuring methods have been suggested in ISO/FDIS 14644-9[2)]. However, most methods have limitations in cumbersome handling, long measurement time, human inaccuracy, high cost and so on.
Based on such circumstances, we developed a measurement instrument that can measure particle concentration on a sampling plate. This direct method can be applicable to ISO/FDIS 14644-9 and categorized as the oblique-, glancing- and side-light measurement systems.

2. General outline of the measurement of surface particle cleanliness

There are two major methods of measurement of surface particle cleanliness according to ISO/FDIS

14644-9, which are the direct method and the indirect method.

2.1 Direct method

Direct method is the method that can measure the surface directly and is categorized in “visual inspection”, “light microscope”, “oblique-, glancing- and side- light measurement system”, “scattered – light scanner”, “SEM” and “AFM” according to ISO/FDIS 14644-9. The methods that are suitable for concentration detection are “light microscope”, “oblique-, glancing- and side- light measurement system”, and “scattered – light scanner” among the five categories.

“Light microscope” is a method that can measure the size and count the number of particles by human eye or image processing after imaging by an optical microscope. The prices are relatively reasonable. It can detect particles as small as about 1 μm. It can also gather information to predict the shape, the color and the material. These are certain benefits to this method. But the area the method can measure is very limited and it takes a very long time to measure larger areas. In addition, inaccuracy can’t be ignored in the case of measurement by a human eye[3].

“Scattered-light scanner” is a method that can detect particles by scanning via laser radiation. The sensor detects the scattered light of laser radiation and the minimum size detected is around 0.07 μm. It can also detect the shape of the particle, but the radiated area is not large so it takes quite a long time to measure bigger areas. The very expensive price is also a limitation of this method.

2.2 Indirect method

Indirect methods are used in the case that direct methods are not applicable due to the limitation of the objective surface. The particles on the surface are extracted by some media or adhesive materials in that case. However it is very difficult to maintain a constant extraction rate. Therefore indirect methods are generally not so accurate.

3. Development of surface particle counter

In most electronics industries, like assembly of optical instruments, fallen particles from the atmosphere are evaluated by measuring surface particle concentration on the sampling plate exposed in the objective environment by light microscope method. The concentration and exposure condition are key information for the evaluation. However, there are some limitations in “light microscope” method as elaborated above. In practical use, human inaccuracy and long measurement time is a major hurdle for this method. Therefore we focused on shorter measuring time, elimination of human inaccuracy, easy handling and economy, and developed a new surface particle counter as an alternative to the “light microscope” method.

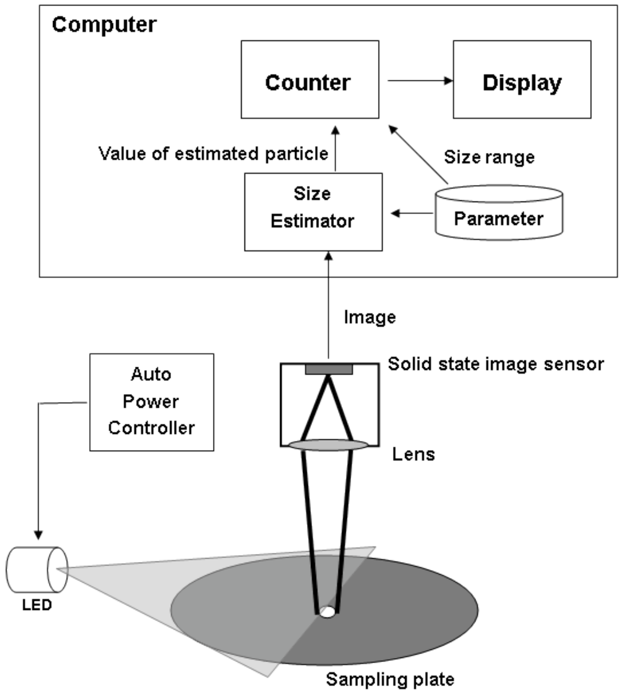

Figure 1. System block diagram of surface particle.

The developed surface particle counter is one of “oblique-, glancing- and side- light measurement system” and counts the number of the particles on the sampling plate. It can classify the corresponding particle size range by detecting the scattering of light from the particle on the plate. It does not use a high magnification microscope and a scanning mechanism. The feature is imaging wide area of the sampling plate at one time. The system organization is shown in Figure 1. The picture of the actual product “Fallen Dust Counter (CSC Co., Ltd.)” is shown in Figure 2. The sampling wafer is made of silicon and has mirrored surface. The diameter is about 100 mm and the diameter of the measured area is about 80 mm. When the sampling plate is exposed to the objective area, the particles in the atmosphere attach to the surface as a result of settling or inertial collision. A particle collection method is written in the literature[1] and this method essentially follows that.

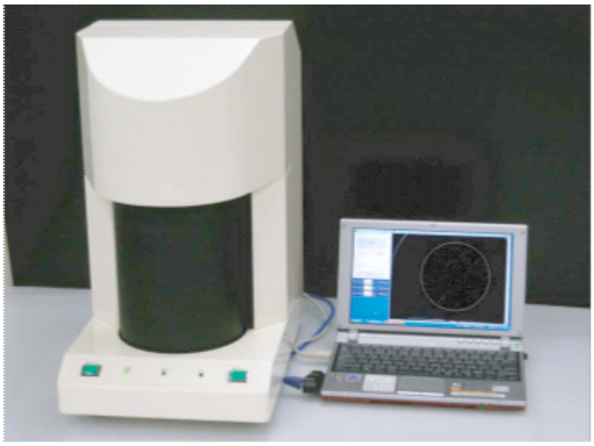

Figure 2. The exterior of surface particle counter.

The sampling plate with the attached particles is set into the surface particle counter and measured. The surface particle counter emits light from an LED light source (White, maximum radiation flux is 3 W) to the plate with a low angle. The attached particles show scattering with certain light intensity according to the size of particles. The scattering form the image into the imaging sensor set on an almost right angle against the light emission through the collecting lens and the image is recorded as the image data. The system identifies the particle sizes from maximum brightness and pixel that has larger brightness than a threshold in the image data. And the obtained data of the particle sizes are compared to the particle size range and categorized accordingly. The particle size ranges are >= 10 μm, >=30 μm, >=50 μm and >=100 μm. The measured results are displayed on the computer as the number of the particles on the measured area and the concentration (particles/m^2) by each particle size range.

The parameters for the identification of the particle sizes are defined by the experiment using the standard polystyrene latex particle (PSL particle). Four sizes of PSL particles are dispersed on the plate, and the parameters are defined by a statistical optimization method by making the sum of least square of the error of the identified size taken from the obtained data and known actual sizes minimum.

The measurement by the surface particle counter is very easy and automatically operated by just pushing the measurement button. It does not scan the surface so the measurement time is very short. Moreover, it does not contain any special light source, lens imaging sensor or complicated mechanisms, therefore it is economical.

4. Evaluation of the measurement characteristics of the surface particle counter

The Counting efficiency and the concentration characteristics were measured in order to evaluate the inaccuracy of the counting by the surface particle counter.

4.1 Counting efficiency

There is no standardized definition of the measurement instrument for SPC in ISO/FDIS 14644-9. But the counting efficiency of airborne particle counter is standardized as follows[4)].

a) The counting efficiency in the case of matching the calibration particle close to the minimum measurable size with the corresponding particle size range is 50 ± 20%.

b) The counting efficiency in the case of matching the calibration particle with the size of 150% to 200% of the minimum measurable size with the minimum particle size range is 100 ± 10%.

We followed the concept of the standard of the airborne particle counter above for the counting efficiency of the surface particle counter.

PSL particles are used as the calibration particle. PSL particles are dispersed on the sampling plate with almost uniform density in high cleanliness environments and measured by the surface particle counter. The number of the dispersed particles in the measurable area is about 200 and it was confirmed by the light microscope method (eye observation)[2)]. The results are shown in Figure 3. Graph A shows the results of 10 μm and 30 μm of PSL particles and Graph B shows that of 50 and 100 μm. Horizontal axis means the particle size equal to or larger than the considered particle size. Vertical axis means the counting efficiency η expressed as the following formula.

$$\eta = C / C_p \times 100\,(\%)$$

C: Concentration counted by the surface particle counter.

C_p: Concentration counted by the "light microscope" method.

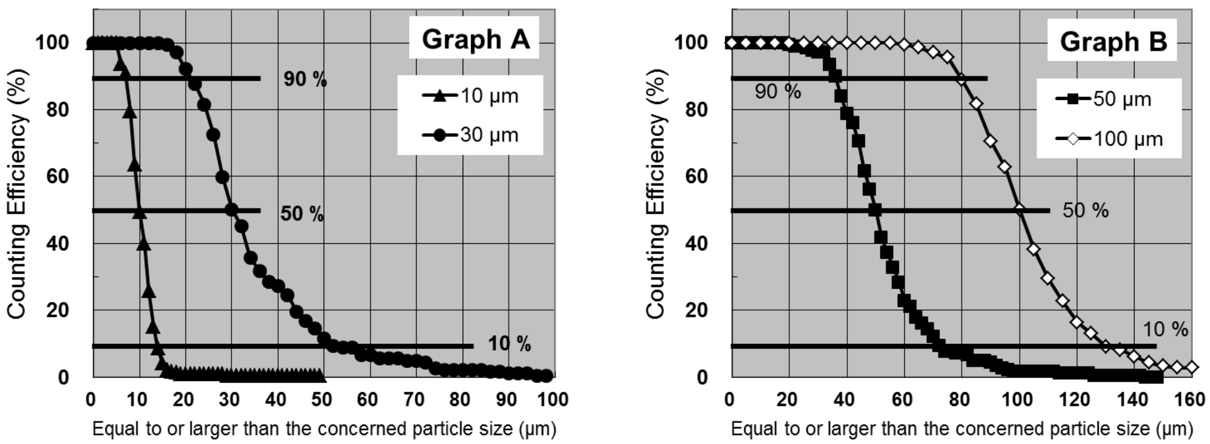

Figure 3. Counting Efficiency of the particle size equal to or larger than the concerned particle size when the PSL particles are measured by the surface particle counter.

This graph shows the change of the counting efficiency in the case of varying the counting particle size, and the steeper change of the counting efficiency means less inaccuracy. It is ideal that the counting particle size that the efficiency becomes 50% corresponds with the size of the measured PSL particles.

Table 1 shows the results of the particle size when the counting efficiencies are equal to 10%, 50% and 90%. In the standard of counting efficiency of airborne particle counter [4], the counting efficiency only at the minimum measurable particle size is defined. But the particle size is expanded to all particle sizes in table 1. In case the particle size of PSL particle and the counted particle size are equal, the standardized condition **a)** mentioned above is satisfied in all 10, 30, 50 and 100 µm PSL particles. And the counted particle sizes that the counting efficiency is 90% become larger than half of each PSL particle size, so this also means the standardized condition **b)** mentioned above is satisfied.

Particle size of the measured PSL particles (µm)	Measured Particle size equal to or larger than the concerned particle at each Counting efficiency (µm)		
	10%	50%	90%
10	13.1	9.6	7.5
30	52	29	22
50	71	53	36
100	128	99	79

Table 1. Summary of the measured particle size equal to or larger than the concerned particle size at each Counting Efficiency taken from Figure 3.

4.2 Measured concentration

10 µm PSL particles are dispersed on the plate as indicated in Section 4.1 and the concentration was measured by the surface particle counter with varying the dispersed concentration.

Figure 4 shows the results. The horizontal axis is the particle concentration measured by the "light microscope" method and the vertical axis is the concentration measured by the surface particle counter. The particle concentration in whole measured area of the surface particle counter is measured by the "light microscope" method. The measured particle size and the particle size of PSL

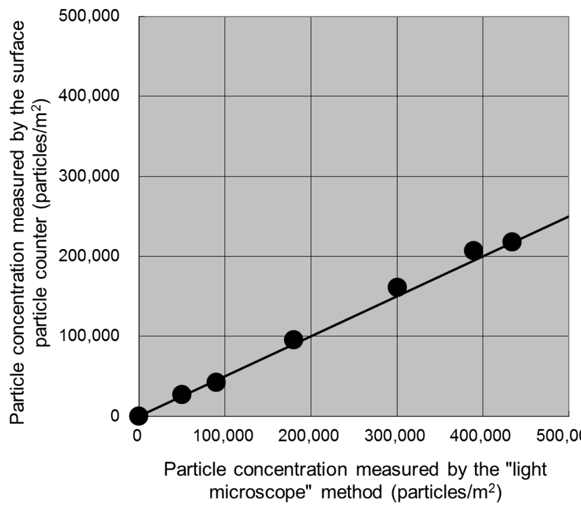

Figure 4. Correlation of the particle concentrations between the surface particle counter and the "light microscope" method.

particle are the same in this measurement by the surface particle counter, therefore it is ideal that the concentration measured by the surface particle counter corresponds to half of the concentration measured by the "light microscope" method.

Regarding the maximum measurable concentration by the surface particle counter, the loss of counting due to the limitation in the resolution must be below 10%. The specification of the maximum concentration is defined as 400,000 particles/m^2 taking into account some margins. The measured concentration by the surface particle counter maintains the proportionality even at around the maximum measurable concentration and corresponds to the results measured by the "light microscope" method.

5. Applications

In addition to the basic application such as monitoring the current state of settling particles in a cleanroom, there are some other applications for the surface particle counter as follows.

5.1. Stamp test (Indirect method)

The attached particles on cleanroom ware, gloves etc. are transferred to the sampling plate and can be measured by the particle concentration. This realizes the evaluation of the surface of such materials. This is one of the "indirect" methods. The transfer rate is not firm but it is good enough to estimate how much dust they have individually.

5.2 Particle elimination test

The surface particle counter can be also used for the evaluation of particle elimination by sticky rollers, air jets[5] and so on. The elimination rate can be estimated by using it before and after cleaning.

6. Conclusion

Focusing on shorter measurement time, elimination of human inaccuracy, easy handling and economy, new measurement instrument (the surface particle counter) of particle with 10 to 100 μm size has been developed. It can be also applicable to ISO/FDIS 14644-9. Through the evaluation of the surface particle counter, it is revealed that the counting efficiency is equivalent to that of a light scattering airborne particle counter. And in the case that the measured particle (PSL particle) concentration is varied, the result of the measured concentration by the surface particle counter is reasonable compared to the concentration measured by the "light microscope" method.

The measurement time depends on the concentration due to the software processing. The approximate measurement time is about 60 sec in case that the concentration is about 100,000 particles/m^2. This means it can drastically shorten the measurement time compared to the conventional "light microscope" method. The operation is also very easy.

Therefore this surface particle counter is very suitable for the industries that have to care about such particles between 10μm and 100 μm as the alternative to the "light microscope" method. This is also applicable to chemical industries like functional films for displays etc.

References

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