A Simple Optical Method for the Measurement of Glass Wool Fiber Diameter

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ABSTRACT

An optical method for measuring glass wool fiber diameter has been proposed and discussed from the viewpoint of practical use. The method is based on both light scattering and light reflection on the glass wool. The method can measure the mean fiber diameter, d, *in the area illuminated by laser light in realtime. The accuracy of the method, i.e., the dimensional resolution, was found to be about* 0·7 *μm within the diameter range of* d ⩽ 7·0 *μm.*

1 INTRODUCTION

Processed goods of glass wool have been widely used for adiabatic and sound proof materials, in particular, in construction and automotive industries. The quality of the goods depends largely on the weight density and fiber diameter of the glass wool. We have developed a realtime densitometer of glass wool using solar cell for industrial use.[1]

In this paper, we propose a simple method for measuring the fiber diameter of glass wool in real time and demonstrate the validity of the method by laser light scattering and reflection on the glass wool surface.

2 PRINCIPLE AND METHOD

The principle of the method is based on scattering and reflection of the laser light on the glass wool surface. The method measures fundamentally a mean value of the fiber diameter in an irradiated area unlike an optical microscope which measures each fiber diameter.

Figure 1 illustrates the principle. The glass wool is pressed by a transparent glass plate and then a flat surface of the glass wool is formed. The laser light illuminated obliquely is scattered and reflected on both the glass wool surface and the glass plate. A semiconductor laser and an Ar ion laser are used as light sources and two photodiodes are used as light receivers. One photodiode is used for the reflected light and the other for the true scattered light. The signal is a scattered light intensity I_s only on the glass wool surface. The scattered light intensity on the glass plate, I_n, is noise and it should be removed. It is, however, impossible to distinguish these signal and noise lights at the receiver experimentally. We then measure only the noise light intensity by using a black cloth in place of the glass wool. The true signal light intensity I_s can then be obtained from both the measured intensity I_t and the noise intensity I_n, $I_s = I_t - I_n$. This will, further, enable us to use any kind of glass plate. That is, if we can use a worn glass plate, for example.

Both the reflected and scattered light intensities will depend mainly on the fiber diameter d and the reflexibility of the glass wool, in particular, on the colour. It will be considered that the reflexibility has the same influence on both the reflected and the scattered light intensities. On the contrary, fiber diameter will have an opposite influence on both light intensities as seen in Fig. 1. The ratio of these intensities, I_r/I_s, will, therefore, depend only on the fiber diameter and not on the reflexibility. We may then use the ratio as a measure of the fiber diameter, which is a basis of this method. Two photodiodes are used for this reason. It is needless to say that the ratio will strongly depend on the optical arrangement.

Both the measured light intensities are amplified, digitized by a 12 bit A/D converter, calculated by a personal computer and displayed. The measurement can be done in an instant, which is one of the greatest merits over the microscopic method usually used.

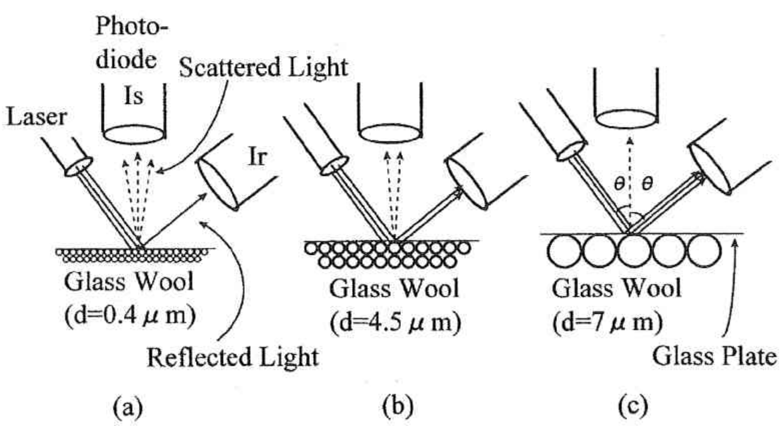

Fig. 1. Optical principle of the method.

3 EXPERIMENTAL RESULT AND DISCUSSION

Figure 2 shows an example of the experimental result by the semiconductor laser of wavelength 640 nm. Both the reflected and the scattered light intensities show true signal components. Each value is a mean of 10 measurements. A fluctuation of each measured value was within 5%. The reflected light intensity I_r increases nearly in proportion to the increase of the fiber diameter d within the range of $0{\cdot}4 \leqslant d \leqslant 7{\cdot}0$ μm. On the contrary, the scattered light intensity I_s changes in inverse proportion to d. Then the ratio of these intensities, I_r/I_s, increases nearly in proportion to d^2 within the fiber diameter range mentioned above. The same result was obtained for the Ar ion laser of wavelength 515 nm. Furthermore, the same result was obtained for other colour of glass wool. Thus, the method does not depend on both the light source and the glass wool, as considered above, that is, it can be used for any light sources and any colour of glass wool.

The curve of the ratio, I_r/I_s, can thus be found to be used as the measure of the mean fiber diameter. The sensitivity of this method, in other words, the dimensional resolution, is basically restricted by the measurement error. The maximum error, i.e., peak to peak error, was about 10% in each measurement. The resolution will then be considered as about 0·7 μm. This will be improved by averaging many measurements.[2]

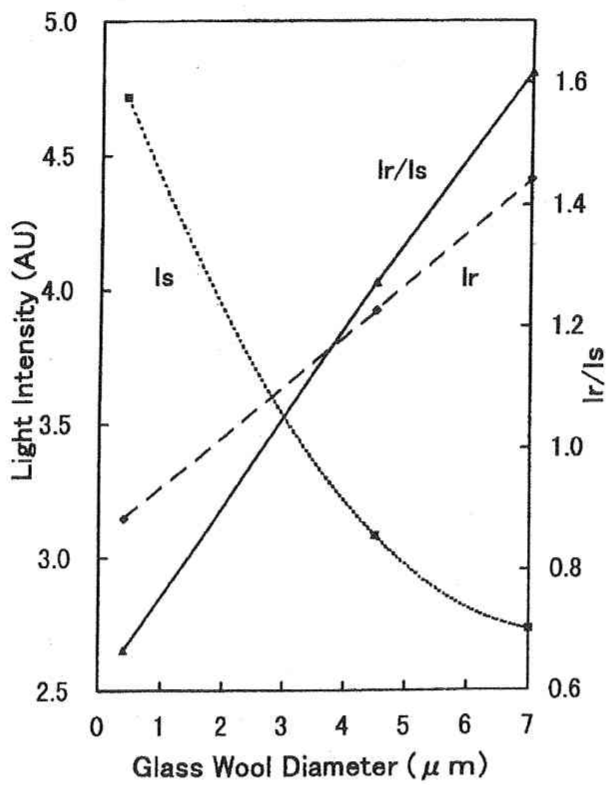

Fig. 2. Reflected and scattered light intensities and the ratio of these intensities versus the glass wool diameter.

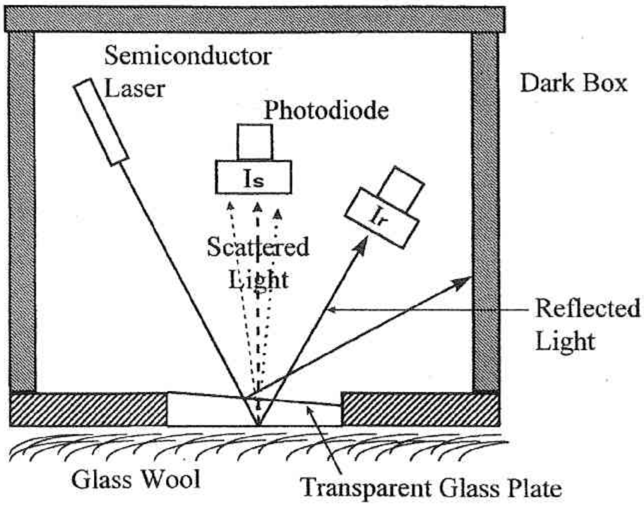

Fig. 3. Proposed sensor head including the laser and the two photodiodes for this method.

Figure 3 shows a proposed sensor head for this method. The semiconductor laser and the two photodiodes are fixed in a dark box to eliminate the noise light, i.e., the ambient light. An optical arrangement, i.e., the position and direction of the laser and the two photodiodes, must be determined by both the intensities, I_r and I_s. A sloped disk glass plate is used to keep away the reflected light on the upper surface of the glass from the one on the lower surface as shown in this figure.

4 CONCLUSIONS

The optical method for measuring glass wool fiber diameter has been proposed and discussed from the viewpoint of industrial use. It has the following features:

(1) it can measure the mean value of the fiber diameter in an irradiated area,
(2) it can measure the fiber diameter in real time,
(3) it has the dimensional resolution of about 0·7 μm,
(4) it can be applied for laser of any wavelength and glass wool of any color,
(5) it is very simple to construct and to use.

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REFERENCES

1. Chen, J., Ueda, M., Asada, K. & Tanibuchi, K., Realtime densitometer for glass wool using solar cells. *Opt. Lasers Engng*, **29** (1998) 61–66.
2. Ueda, M., Mizuno, S., Matsumura, A. & Tohjyo, F., Light attenuation in a semi-transparent foam sheet—thickness measurement for industrial use. *Opt. Lasers Engng*, **24** (1996) 339–50.