An optical system for measuring the eccentricity of glass wool pipe-for industrial use

An optical system for measuring the eccentricity of glass wool pipe — for industrial use

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Abstract

An optical system for measuring the eccentricity of the glass wool pipe has been developed for an industrial use. The system consists of a contact sensor, a photo light sensor and a signal processing system with a logic circuit. The system is simple, fast and efficient for practical use; it allows implementation of on-line process monitoring and alarm warning signals for unacceptable pipe eccentricity during manufacturing.

1. Introduction

The glass wool and fiber have recently seen widespread applications. They are dust-proof papers in semiconductor factories, separators to insulate electric current in batteries, heat- and sound-resisting mats employed in automobiles and buildings. The efficiency of the finished goods depends mainly on the uniformity of weight density of raw glass wool when it is used in mats, fiber diameter when it is used in filters, and thickness when it is used in pipes. We have developed an optical system for monitoring the weight density of raw glass wool [1,2] and the thickness of a semi-transparent foam sheet [3,4] by passing light through them. Further, we have developed a system for measuring the mean diameter of optical fiber by reflected light [5,6]. A light interacting with the measured object can be used directly in all these methods since the objects are semi-transparent and roughly constitute a flat plane.

Another example of glass wool application will be in a pipe for protecting against heat and cold of a metal pipe through which water, steam and other fluids flow. The deviation of the pipe's thickness, i.e., an eccentricity, will be most important for a practical value. The eccentricity has hitherto been measured by CCD camera. This method has two distinct disadvantages. Firstly, it can only measure eccentricity at the edge and not at the center region of the pipes. Secondly, measurement errors are produced by a lack of clarity due to broken pieces of the glass wool. The technique in this paper for measuring eccentricity of glass wool pipe is simple and efficient, and further it does not possess the disadvantages inherent with CCD camera method.

In this paper, a practical system for detecting the eccentricity of a glass wool pipe has been developed optically by a hybrid method. The thickness of the pipe is measured by the contact method and the displacement of a contact head is measured by an optical method.

2. Principle and method

Fig. 1 shows the photographs of the glass wool pipe and Fig. 2 the schema of the pipe's cross section. The pipe usually has an eccentricity, i.e., a deviation of the thickness. This caused a serious problem at a junction when it was used to cover the iron pipe in practice. An unacceptable pipe having too large an eccentricity should then be rejected. The eccentricity of the glass wool pipe can, usually, be defined as

$$e = (t_{\max} - t_{\min})/(2t_n), \quad (1)$$

where $t_{\max}$ is the maximum thickness of the glass wool pipe, $t_{\min}$ the minimum thickness and t_n the mean thickness, or defined thickness. By the method described in this paper, the eccentricity can be measured in all directions as the pipe rotates in a 360° arc, i.e., 1 cycle.

The cross section of the glass wool pipe was usually unclear due to the chips in cutting. Further, the pipe itself was too soft for the thickness to be accurately measured. These make the CCD camera method difficult. It is thus necessary to use the contact method by loading a constant pressure on the surface for an accurate measurement of the pipe's thickness. For this purpose we developed a hybrid sensor system consisting of two sensor heads; a contact head and a light head.

Fig. 3 shows the hybrid sensor system. Fig. 3(a) shows a whole view of the system and Fig. 3(b) an enlarged view of the sensor. Both ends of the glass wool pipe are held on the pipe support. The contact head with a rotator is placed on the pipe as shown in Fig. 3 and imposes a constant pressure on the pipe, which enables an accurate measurement. The measurement can be done at any position in the axial direction of the pipe. The CCD camera method can only measure the eccentricity of the cross

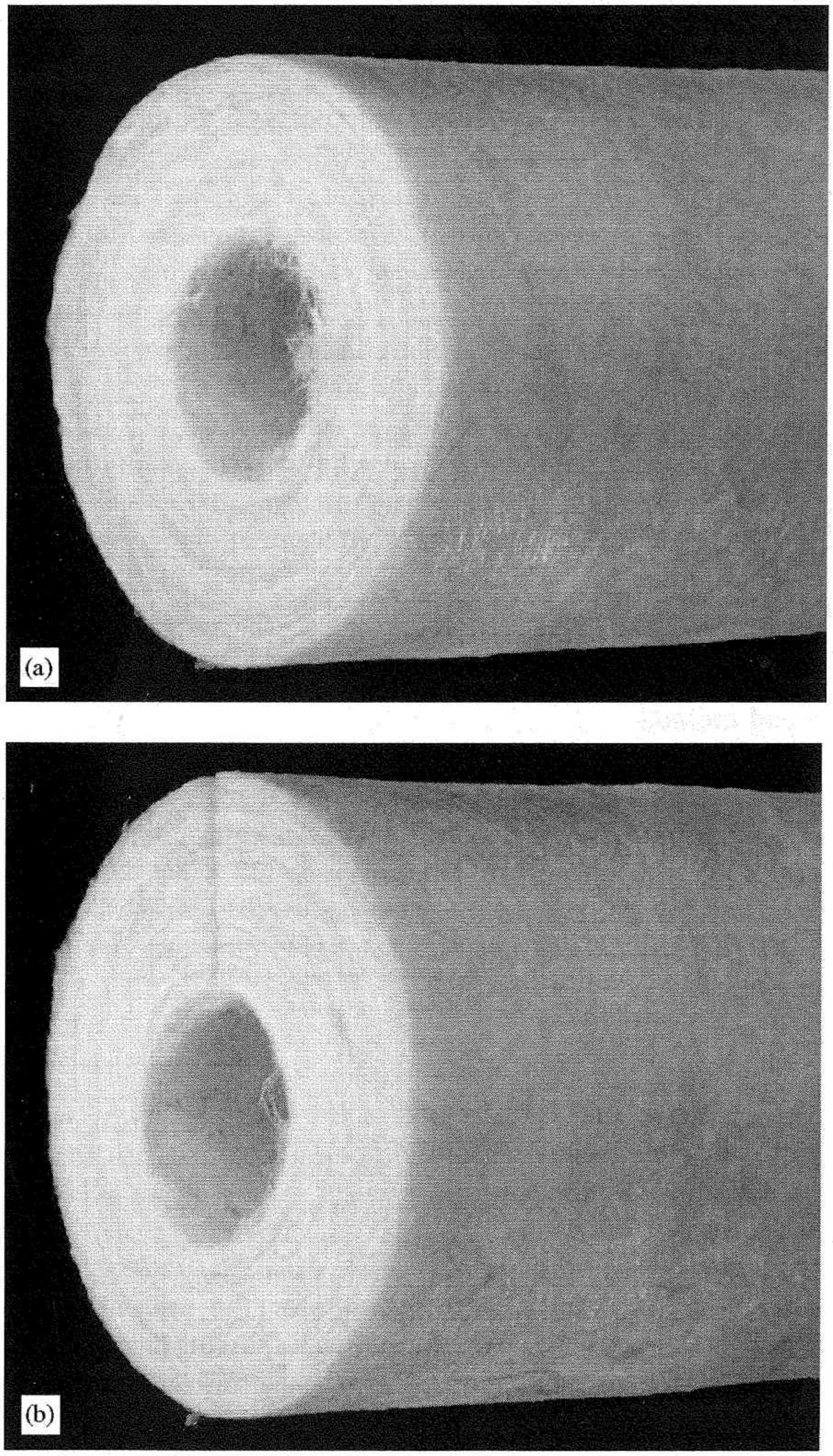

Fig. 1. Photographs of physical glass wool pipe: (a) without a cut and (b) with a cut.

section at the end. As the pipe rotates, the contact head will be displaced up and down according to the thickness of the glass wool pipe. A sheet-like laser light was used to measure the displacement of the contact head. That is, the light sensor can accurately detect the displacement since the light intensity is in proportion to the pipe's thickness.

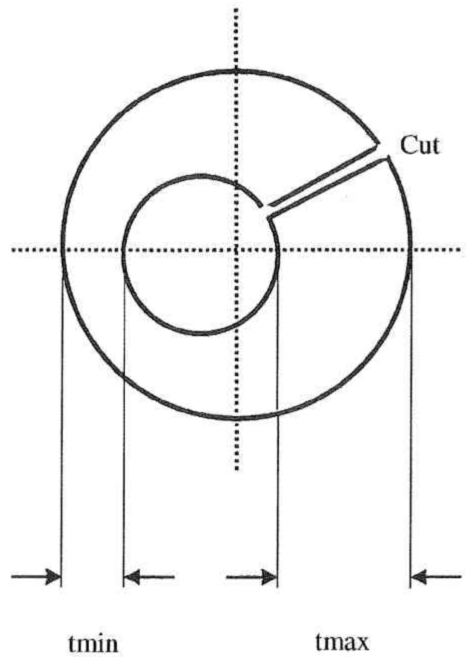

Fig. 2. Definition of eccentricity.

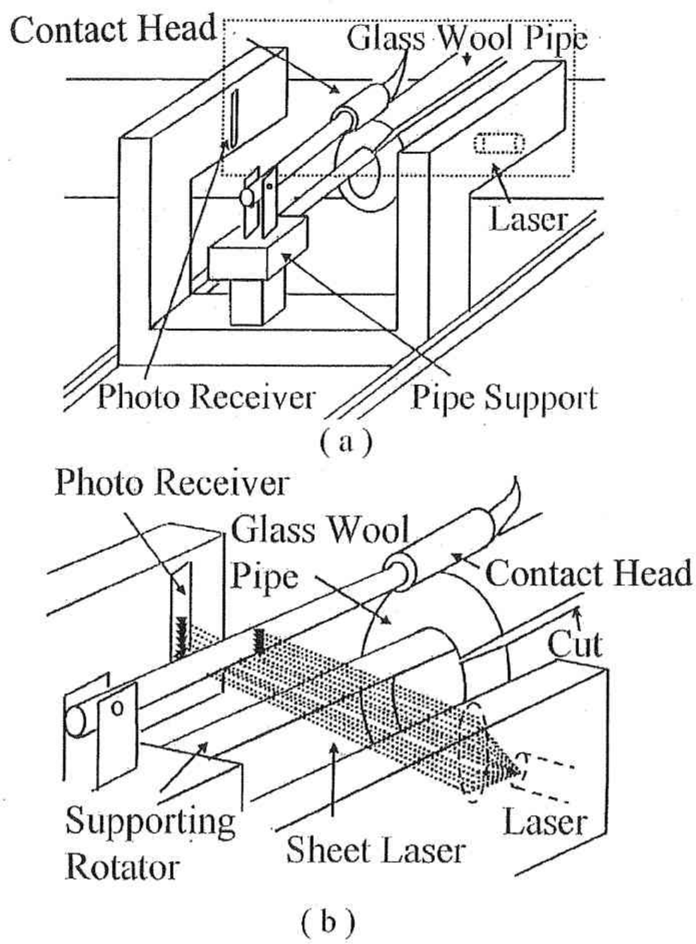

Fig. 3. Schema of the hybrid sensor system consisting of two sensor heads; (a) whole view of the sensor system, and (b) an enlarged view of the contact and optical heads.

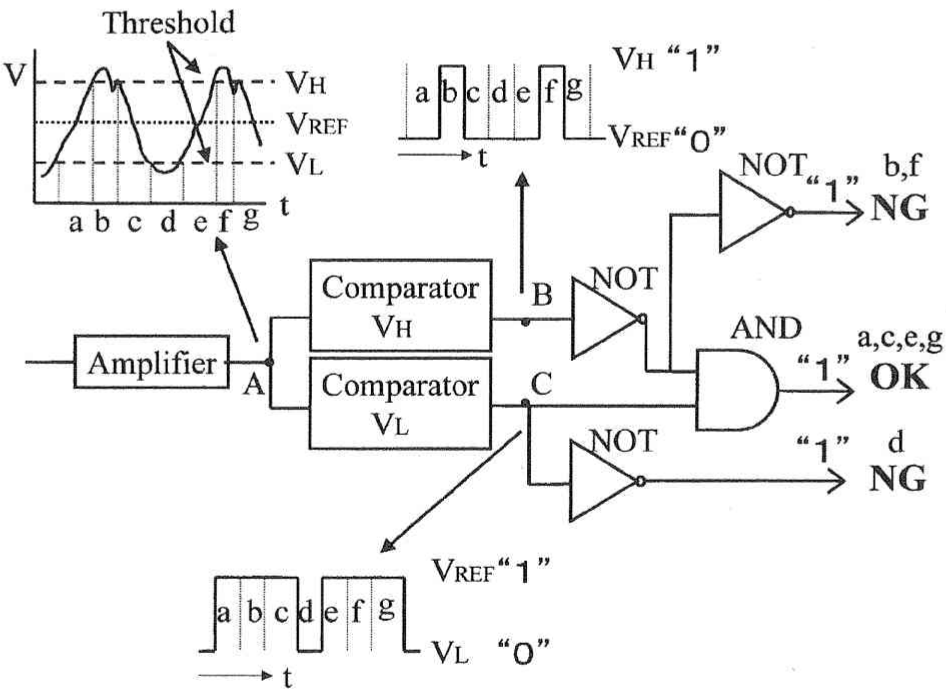

Fig. 4. Electronic circuit to measure the thickness of the glass wool pipe without a straight cut for judging its quality as acceptable or unacceptable.

The dusts on a laser and a photo light receiver cause a measurement error when the system is used in a practical plant. The problem will be solved by using the windows on them and by wiping off the dusts periodically. Another solution for the problem will be to normalize the light intensity through the gap in each measurement by the light intensity through a constant gap.

In practical applications, pipes having too large an eccentricity should be removed. Fig. 4 shows an electronic circuit for this purpose. An analog signal for the thickness will be obtained on the amplifier, as shown in a cut. A signal for the quality can, finally, be obtained by this logic circuit. That is, the signal for the inferior goods, i.e., the pipe having lager eccentricity than the pre-defined one, e_n, is expressed by "NG" and the one for superior goods by "OK". The signal of "NG" is obtained if the analog signal at any time during a rotational cycle only exceeds the range between V_H and V_L, both of which are determined by e_n. The logic circuit is reset in every rotational cycle and the next reading starts. The value of e_n is usually 10–20%, which is determined according to the mean thickness of the pipe.

The signals of "NG" and "OK" will be required only for practical applications. The analog signal for all the directions, i.e., over a 360° arc, will, however, be shown in this paper to examine the eccentricity in detail.

3. Results and discussions

Preliminary experiments were carried out using pipes without a cut. Fig. 5(a) shows a representative result for a pipe with small eccentricity i.e., for superior quality, and

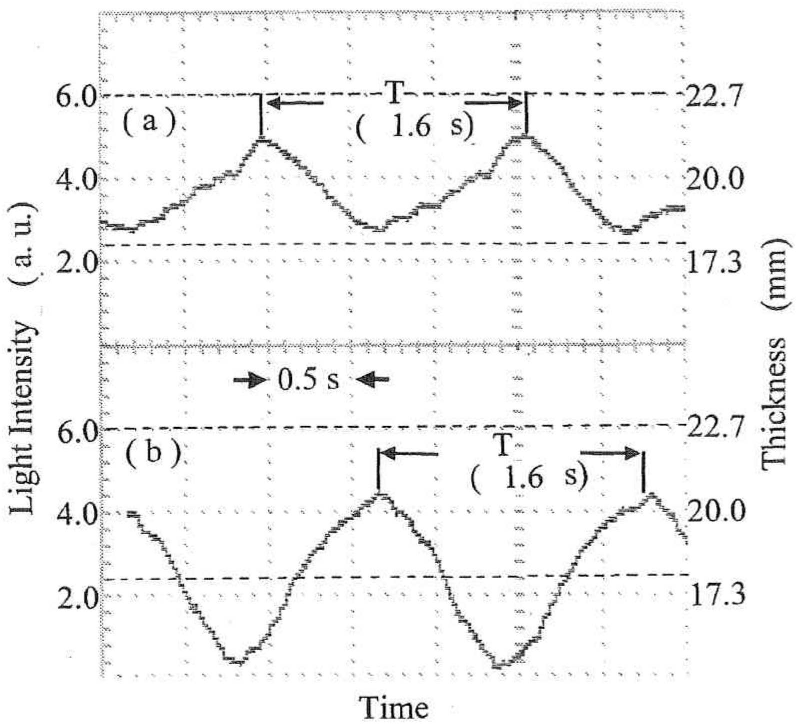

Fig. 5. Thickness of the glass wool pipe without straight cut: (a) with small eccentricity, and (b) with large eccentricity.

(b) with large eccentricity i.e., for inferior goods. T shows a period for 1 cycle and was about 1.6 s in all the experiments. In this case, the pre-defined eccentricity was $e_n = 0.13$.

The glass wool pipe is usually 1–2 m in length and should be cut in that direction which is used for covering iron pipe, vinyl pipe and other types. In practical applications, it is difficult to measure pipe thickness previous to cutting.

Fig. 6 shows the result for a pipe with the cut which is practically applied. A decrease in pipe thickness occurs suddenly at the edge of the cut as shown in this figure, and this will cause an error when judging for superior or inferior quality. A misjudgment occurs only at the thin region as shown in Fig. 6(b) and does not occur at the thick region as shown in Fig. 6(a).

The degree of misjudgment was, however, negligibly small in the context of practical use when the open area of the cut was rather small. When the open area was larger than about 20° arc, a misjudgment arose. This problem can, however, be solved by using another photo light sensor to detect the cut.

Fig. 7 shows an electronic circuit designed for this purpose. The sensor signal to detect the cut, E_2, can successfully be used to suppress the sudden change of E_1 at the cut by means of the sample holding circuit. Then, the logic circuit will accurately judge the quality of the goods. That is, the circuit will display "NG" when the eccentricity is over the defined one, e_n, and "OK" when it is smaller than e_n.

Fig. 8 shows the result obtained by this sample holding circuit. The sudden change in thickness at the cut has been kept at a constant value and thus the circuit in Fig. 7 will make an accurate judgement for practical use.

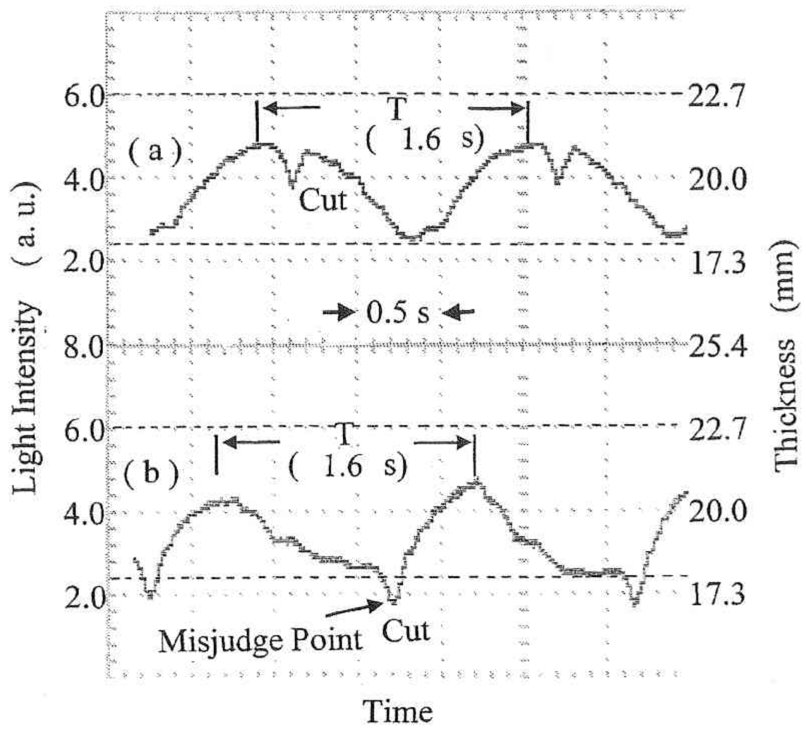

Fig. 6. Thickness of the glass wool pipe with a cut: (a) the cut exists at a thick region, and (b) the cut exists at a thin region, which yields misjudgment.

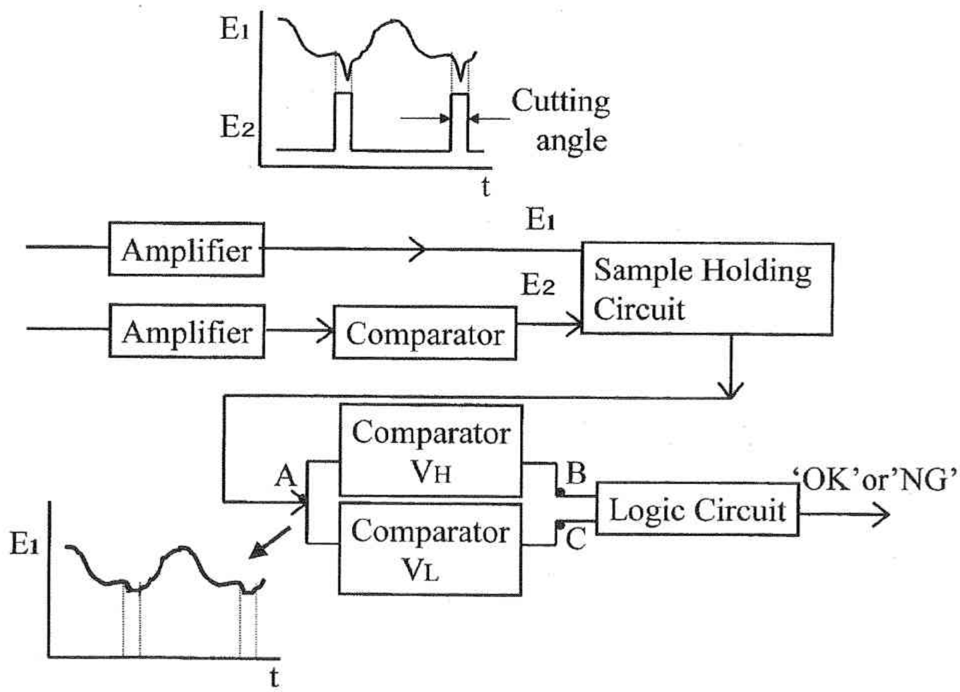

Fig. 7. Electronic circuit with a sample holding circuit to compensate an error due to the straight cut. Connections A, B, and C, in this circuit correspond to A, B, and C in Fig. 4.

The time for a rotational cycle, i.e., period T, was about 1.6 s in this experiment. The minimum time necessary for the measurement was, practically, about 1 s; when the minimum time was shorter than 1 s, the contact head vibrated as the glass wool pipe rotated and misjudgment occurred. However, eccentricity measurements may be

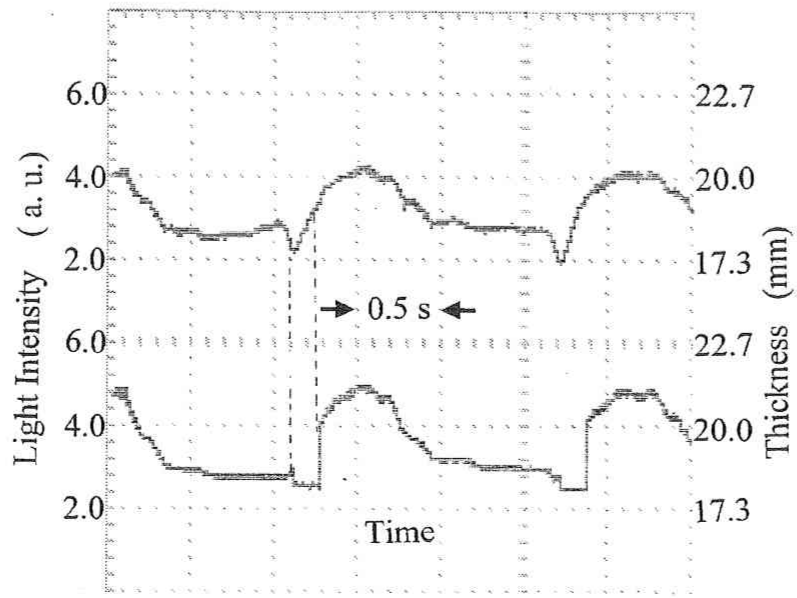

Fig. 8. Suppression of the sudden decrease in thickness at the cut by using the sample holding circuit shown in Fig. 7.

achieved at a higher pipe rotational speed if the dynamic responses of the contact head and glass wool pipe are understood. The time of 1 s, was, however, short enough in the practical application.

Thus, the signal processing system allows implementation of on-line process monitoring and alarm warning signals for unacceptable pipe eccentricity during manufacturing.

4. Conclusion

A practical system for measurement of the thickness of glass wool pipes has been developed by using a hybrid sensor system consisting of a contact sensor and an optical sensor. The sensor system has two main merits in its high accuracy and high speed, and in its simplicity of construction. The system has now been successfully applied to a practical situation.

Acknowledgements

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