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Non-contact detection for quantity-insufficiency in tablet counting machine

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A non-contact method based on light reflection was developed to detect quantity-insufficiency information of the tablet counting machine in medicine packaging industry. The incident light beam coming from a detection unit illuminates the detection area. A detector embedded in the detection unit collects the reflected light rays. If one tablet-missed event happens, the detector will output intensive pulse signal. By analyzing the gathered signal, the detection device can recognize that there is not a tablet in current pit. High signal-to-noise ratio was observed in the experiment, so the recognition is readily accomplished. The detection device has been applied in practical industry. It reduces the omission rate low to one hundred-thousandth, far less than three thousandth under best vision monitoring by human.

Keywords: light reflection; tablet-missed; moving pits, detection.

1. Introduction

In medicine bottled packaging industry, with the ever-intensifying implementation of Good Manufacturing Practices for Drugs standard among Chinese medical enterprises, tablet counting machine [1, 2] becomes a very important apparatus. Tablets shall be distributed in all the pits of one circular mold board of a tablet counting machine. Once there are no tablets in some pits, there will be mistake in the number of tablets packaged in one bottle, namely the unqualified quantity-insufficiency. To avoid such situation, each tablet-missed event, namely that there is not a tablet in currently detected pit, should be recognized so as to weed out the unqualified bottle.

Vision monitoring by human is first considered. But it has many disadvantages such as low efficiency and high omission rate. Machine vision inspection [3–5] is advanced and easy for operation. However, it is very demanding about calculation which involves complicated pattern recognition. One tablet counting machine usually needs to satisfy several types of mold boards and many shapes and colors of tablets, which increases the recognition difficulty in machine vision inspection. Further more, it is expensive compared with other automatic detection systems.

This research adopts a non-contact detection method based on light reflection to monitor the tablet-missed events. The detection device analyses the signals received from detection units and outputs quantity-insufficiency information. Compared with machine vision inspection, this method is of low cost and simple in principle of detection.

2. Principle of detection

There are many pits in a circular mold board of a tablet counting machine. When the tablet-counting machine works, the circular mold board also rotates. Those moving pits at the same radial position are monitored by one fixed detection unit. They one by one pass through the detection area under the detection unit, just like illustrated in Figure 1.

The optical reflection method is selected because there is a different reflection property between the bottom of the pit and the tablet in the pit. The pit bottom has high reflectivity but the tablet has a dispersive character, so the light rays reflected from the tablet can only partially be collected by a detector (see Fig. 1**a**). In addition, the incident light beam has an angle, which induces that the light reflected from the upper end-face of the pit fails to enter into the detector (see Fig. 1**b**), while the light reflected from the bottom of the pit can enter thoroughly (see Fig. 1**c**). Therefore, the collected light rays reflected from the pit bottom are far more than those from the tablet or the upper end-face. So, if there is a pit without one tablet in it passing through the detection area, the detection device can immediately recognize a tablet--missed event according to the received intensive pulse signal.

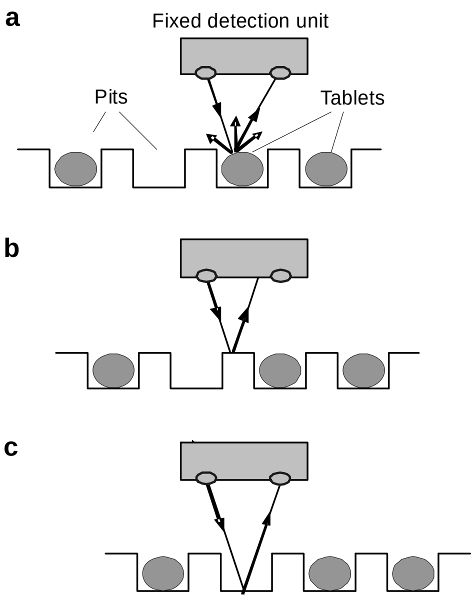

Fig. 1. Reflection to the incident light in detection area by objects of (**a**), (**b**) and (**c**). Pit with one tablet in it (**a**); The upper end-face of pit (**b**); Pit without one tablet in it (**c**).

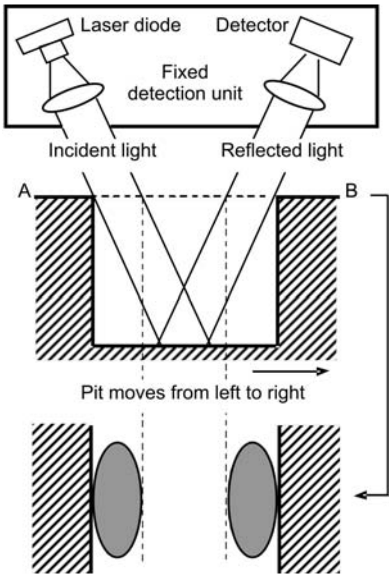

Fig. 2. Optics layout for tablet-missed information detection.

Figure 2 shows the detailed optics layout constructed with one detection unit and its detected objects. The detection unit is fixed, while the pit moves. The incident light beam comes from a laser diode and its optical alignment system, but where the beam shaping is omitted. The section of the light beam presents an elliptical shape even at the upper end-face AB of the pit. The reflected light rays are collected by objective lens mounted in front of the detector. The sizes of pits in one type of a mold board are the same but different in the others, so the distance between the detection unit and the pit bottom, as well as the angle between the incident light and the reflected light, should be designed as per the maximum depth-width ratio of the pit. In this way, when the incident light beam fully enters the pit, the reflected light can just leave from the pit as shown in Fig. 2; that is to say, the moving pit has only one position not blocking the incident and reflected light. For those pits with lower depth-width ratio, they have more positions to let the incident and reflected light into or out of the pit completely.

If there is a tablet-missed pit, then when it scans the detection area, the reflected light and the incident light will be blocked by the internal side-face and the upper end-face of the pit, respectively. The luminous flux received by the photoelectric detector will change from small to large and then from large to small. By analyzing the signal from the detector, tablet-missed information may be achieved.

3. Calculation and simulation for tablet-missed signal

What shown in Fig. 3 is derived from Fig. 2. It simplifies and abstracts the inter-relationship between the elliptical light spot and the pit boundary.

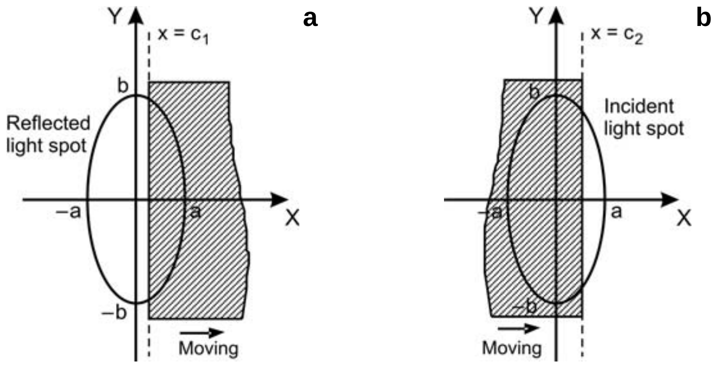

Fig. 3. Impact of the moving pit boundary on the incident or reflected light spot. The detection signal enlarges when the right pit boundary scans from *X*-axis position $-a$ to a (**a**) and diminishes when the left pit boundary scans from *X*-axis position $-a$ to a (**b**).

When the pit scans from left to right in the detection area, the incident light falls to the pit first, then with the right moving of the right boundary $x = c_1$, the reflected light emerges gradually as shown in Fig. 3**a**. The luminous flux received by the detector becomes larger, and it gets the largest value at position of $x = a$. Then the incident light is blocked gradually by the left boundary of the pit. With the continuous moving of the left boundary $x = c_2$, the luminous flux decreases gradually and to zero at position of $x = a$ as shown in Fig. 3**b**.

Suppose that the intensity distribution of light spot is uniform. In Figure 3**a**, when the right boundary scans from left to right, namely from $x = -a$ to $x = c_1$, the detection signal will be:

$$S = 2\int_{-a}^{c_1} \frac{b}{a}\sqrt{a^2 - x^2}\,\mathrm{d}x = \frac{\pi ab}{2} + \frac{bc_1}{a}\sqrt{a^2 - c_1^2} + ab\arcsin\frac{c_1}{a} \tag{1}$$

In Figure 3**b**, when the left boundary scans from left to right, namely from $x = c_2$ to $x = a$, the detection signal will be:

$$S = 2\int_{c_2}^{a} \frac{b}{a}\sqrt{a^2 - x^2}\,\mathrm{d}x = \frac{\pi ab}{2} - \frac{bc_2}{a}\sqrt{a^2 - c_2^2} - ab\arcsin\frac{c_2}{a} \tag{2}$$

Because the optical system is designed to suit the maximum depth-width ratio of the pit, the detection signal has only one point with maximum value; when the depth--width ratio of the pit becomes smaller, there will be a flat zone of the signal wave. Figure 4 shows the numerical simulation of the detection signal according to formula (1) and (2), where $a = 1$ mm and $b = 3$ mm. The abscissa denotes the scanning position c in units of mm (assume $c = 0$ while the pit moves at position shown in Fig. 2), and the ordinate denotes the detection signal in any units. The simulation indicates that

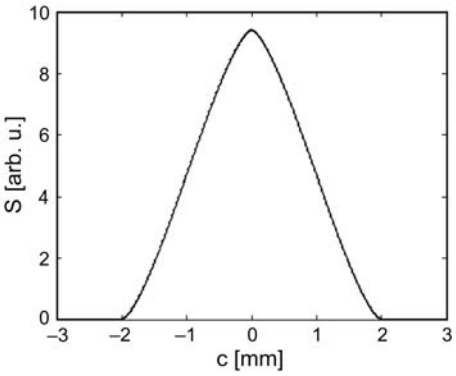

Fig. 4. Numerical simulation of detection signal.

when the boundary of the pit scans from the left to the right in a range of 4 mm, the detection signal changes from weak to strong and then from strong to weak.

4. Experiment and result

The above principle calculation and simulation is similar to the actuality. In real device, many factors need to be considered, including the depth-width ratio of the pit as well as the absolute depth of the pit. When the pit is deep, the reflected light from the up end-surface will generate large transverse displacement, which is inaccessible by the detector. When the pit is shallow, the transverse displacement will not be so large, so part of the reflected light rays may get into the detector and generate extra photoelectric signal to lower the signal-to-noise ratio. However, the reflectivity of the bottom of the pit is larger than that of the up end-surface of the pit, so this impact is slight. As for the contents in the pit, such as tablets, due to its dispersion feature and its thickness, its reflection to incident light is even worse than that of the up end-surface of the pit.

Figure 5 shows the waveforms obtained from our experiment. The waveform shown in Fig. 5**a** is similar as that shown in Fig. 4. However, there are still differences,

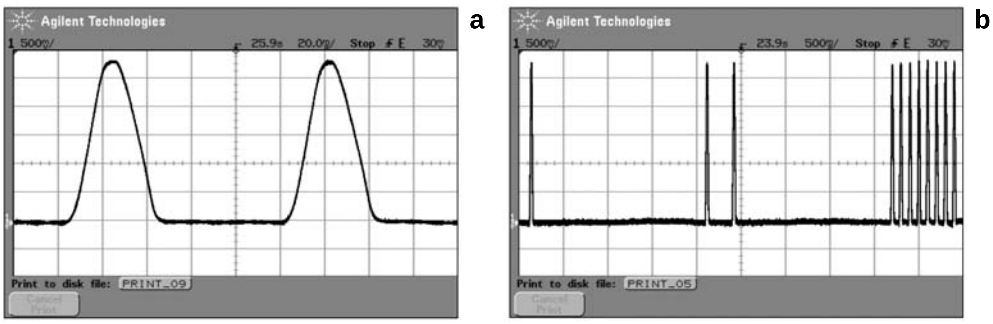

Fig. 5. Signal waveforms recorded in experiment for tablet-missed information detection: wave details (**a**), signal sequence (**b**).

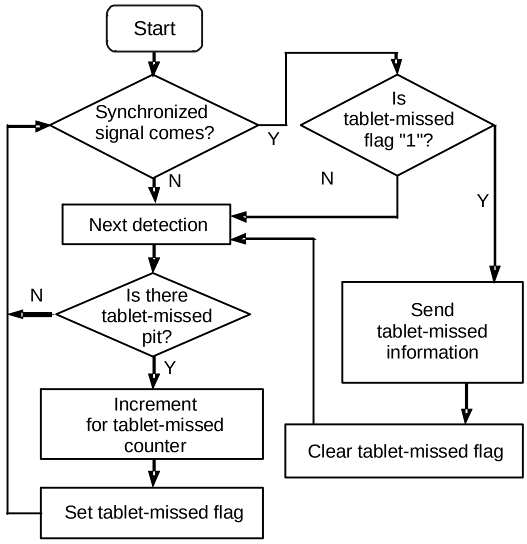

Fig. 6. Control flow chart for tablet-missed information detection.

which is partially caused by the fact that the pit is round in shape instead of square. Figure 5**b** expresses a segment of continuous detection. The obvious sharp peaks mean that there are several tablet-missed pits. Meanwhile, the high signal-to-noise ratio can be clearly observed.

Figure 6 is the control flow chart for obtaining tablet-missed information. The control routine of the detection device continuously checks the tablet-missed event. If one tablet-missed event is detected, the tablet-missed counter will increase by one, meanwhile the tablet-missed flag will be set “1”. The key signal is the synchronous one offfered by the tablet counting machine. When the synchronized signal arrives, the detection device outputs the quantity-insufficiency information to the tablet counting machine, including the tablet-missed flag and the number of tablet-missed events.

5. Conclusions

The photoelectric non-contact method is easy and reliable in tablet-missed information detection of the tablet counting machine. In actual detection, many factors should be considered such as depth-to-width ratio, absolute depth of the pit, shape of light, moving speed of the pit and refresh frequency of the synchronized signal.

The photoelectric signal obtained has a high signal-to-noise ratio and thus has a strong anti-interference capability. The detection device has been applied in a practical tablet counting machine. It reduces the omission rate down to one hundred-thousandth, far less than three thousandth under best vision monitoring by human. A granted Chinese patent based on the above principle has been gotten.

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