Design and improvement of laser sorting system

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Abstract: Camera sorters are used both for food and non-food applications like french fries, shrimps, vegetables, snacks, raw cotton, plastics, etc. But invisible foreign bodies, such as glass, or defects with exactly the same color as the product may not be detected. So the laser scanning system is used for detecting defects when the products and the defects have the same color. A laser sorting system is designed and improved based on the selective absorption principle. And a high-speed signal sampling experiment and a imaging experiment for the system were tested. By the selective absorption sorting technology, both products and foreign bodies were identified efficiently in the signal sampling experiment. The headline in the newspaper was selected as the imaging experimental sample and the diameter of scanning spot was adjusted close to 0.35 mm. The scanning data recorded through computer program was imaged by software. The resolution of the experimental result is 180*43 pixel. Imaging results illustrate that defects (1.5 mm) can be recognized accurately. Finally, after optical scanning system was analyzed, the phenomenon was found that most of the flux was lost due to the non-perpendicular illumination of the sample. A curve scanning sorting structure was proposed for improving traditional sorting system.

Key words: laser scanning; co-optical path imaging; electro-optical detection; foreign body recognition

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激光分拣系统的设计和改进

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摘　要: 相机分拣机常用于食品和非食品分拣,如炸薯条、虾、蔬菜、小吃、棉花、塑料等。但有些看不见的异物(如玻璃)或与产品颜色相同的异物是无法由相机检测到的。而激光扫描系统则可用于检测与产品颜色相同的异物。设计和改进了基于选择性吸收原理的激光分选系统,并对系统进行了高速信号采样实验以及成像实验。在信号采样实验中,系统可以通过选择性吸收分选技术有效识别产品和异物。在成像实验中,选择报纸的标题作为成像样图,调整扫描光斑直径接近 0.35 mm,扫描后的数据经由计算机程序转码并成像。实验成像的分辨率为 180×43 pixel。成像结果表明,系统可以有效地识别 1.5 mm 的异物。最后对光学扫描系统进行了分析,发现部分的光信号损失于扫描光的非垂直入射,于是提出了曲线扫描分拣结构用以改进传统分拣系统。

关键词: 激光扫描; 共光路成像; 光电探测; 异物识别

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0 Introduction

In recent years, people pay more attention on the quality of the food, especially for tobacco and vegetables[1-2]. In order to further improve the quality of products, efficient and reliable sorting equipment is needed to sort products mixed foreign bodies such as glass, wood, paper, plastic, metal, clay, cocoon, cardboard. So, how to design an effective and accurate sorting system to identify and sort out the impurities mixed in food stream is the key question.

At present, most of the domestic tobacco factories use metal detector and digital image sorting equipment to exclude foreign bodies, and supplement by artificial sorting. But the yield is not ideal, and the sorting rate is low. The influence brought from low precision and efficiency of manual sorting is great. Several manufacturers imported the sorting equipment from abroad. But they may encounter problems such as the high prices and the difficulties of maintenance. Therefore, effective online sorting system research has an important significance in improving the international competitiveness of the domestic products.

Camera sorting system can′t accurately identify foreign body when the color and shape of foreign body are similar or identical with the products. But by using the laser, the sorter can realize the analysis of target point by point, and accurately identify the foreign body. Laser sorting system has high precision, faster recognition etc. And laser sorters get more and more extensive attention in the tobacco and vegetable food sorting areas recently.

1 Introduction

Four different physical phenomena can occur when a laser beam interacts with a biological product. These are respectively selective absorption, fluorescence, absorption in the near-infrared and reflection. Both surface and internal reflection were taken into account[3-5]. These phenomena can be selected for the sorting process.

The process of selective absorption is strongly related with the color of the products. If people need to identify products of color A in a stream of products of color B, selective absorption can be used for the sorting of the products. The absorption spectra of four examples measured with an optical spectrum analyzer is given in Fig.1. These spectra show the intensity of the absorbed light as a function of the wavelength. Tobacco leaf strongly absorbs green light when it is illuminated with white light. The green and red wavelengths are partly absorbed and as a consequence the reflected wavelengths (via scattering) are yellow. This is the reason why a tobacco leaf appears yellow to us. The same argumentation is valid for a green rubber (see Fig.1), a strong absorption for blue and red wavelengths has been measured and as a consequence the reflected light will be green. From the spectra of the glass sheet in Fig.1, all wavelengths are almost not absorbed and as a consequence that the glass sheet are transparent. From the spectra of the plastic film in Fig.1, all wavelengths are slightly absorbed and as a consequence that the plastic film are semitransparent.

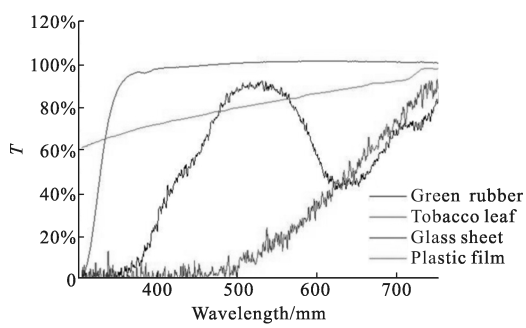

Fig.1 Absorption spectra of green rubber, tobacco leaf, glass sheet and plastic film

How can people use the information from the measured absorption spectra to sort tobacco leaf ? In practice the absorption spectra of the different products can be compared and the wavelength in which the difference in absorption between the products is maximal can be selected. From Fig.1, the maximum absorption difference between both product and foreign bodies is situated around 532 nm. Instead of measuring the absorption spectra, the intensity of the reflected light can be measured as a function of the wavelength (Fig.2 gives the schematic view after the illumination of the products with a green laser).

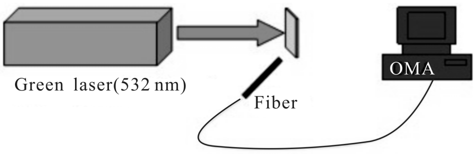

Fig.2 Schematic view of reflected light detecting

Figure 3 shows the experimental results. As earlier explained, this is due to the strong absorption of the tobacco leaf around the wavelength of 532 nm. Generally, if people want to identify brown objects inside a stream of tobacco leaf, the products should be illuminated with a green laser. If the reflected intensity is analyzed, the foreign body can be identified. The tobacco leaf strongly absorbs the green light and the reflected intensity will be low. The foreign body on the other hand absorb only a small part of the incident light and as a consequence the intensity of the reflected light will be high (the background of the glass sheet is tobacco leaf, so the reflected intensity of the glass sheet is close to the tobacco leaf).

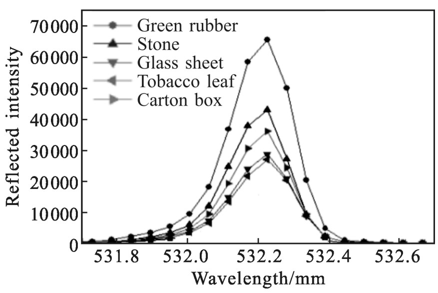

Fig.3 Reflected intensity of green rubber, stone, glass sheet, tobacco leaf and carton box

2 Design

The designed system(see Fig.4) is provided with several light sources 1 and 2 which each generate an intense, focused band of light. Both light sources 1 and 2 generate light of different frequency and are brought together into a band of laser beams by some selectively semi-reflecting mirrors 3 (dichroic mirror). This light band is reflected towards a moving polygon mirror 4. The faces 5 of this mirror 4 are reflective and are set at essentially the same angle to one another. Furthermore, this prismatic mirror 4 rotates around its central axis at an essentially constant speed. The light band falling on such a face 5 is directed towards the product to be sorted. As a result of the rotation of the mirror 4, the light band falling on the faces 5 moves transversely across the stream of parts of the product. In doing so, said band moves each time in the same direction between two positions over the width of the stream, as shown by the arrow.

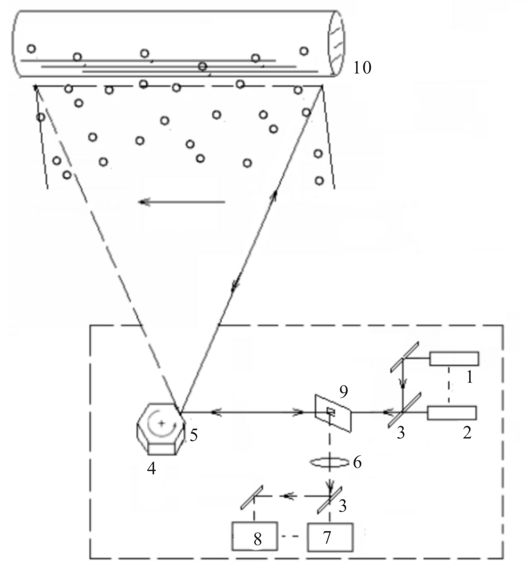

Fig.4 Schematic view of optical part of scanning system

The frequency of this movement depends on the speed of rotation of the mirror 4, and consists preferably of between 500 and 8 000 movements per second. Said detection zone extends between the two positions of the light band, where still a measurement of the scattered light is carried out. When the light band falls on a product via face 5, scattered light is at least partly captured by the same face 5 and is led along approximately the same path as the light band to a beam splitter 9 which reflects the scattered light at an angle via a lens system 6 to a so-called beam splitter (selectively semi-reflecting mirrors) 3. The beam splitter 9 has a central opening which enables the light band2 from the light sources 1 and 2 to pass through unimpeded. The beam splitter 3 separates the light scattered by the product and originating from the respective light sources 1 and 2 into two light bands of different frequency. One band then falls on a detector 7, while the other band falls on a detector 8 via the mirror 9[6].

The system is provided with a background in the form of a tube 10 extending perpendicularly to the direction of displacement of said product, in such a manner that the light band falls on it, where the product move over said tube 10. This tube 10 preferably has the same characteristics as a good product as regards the scattering of the light band.

3 Experiments

3.1 Sorting signal test

According to the design of the light path, red light semiconductor lasers (665 nm) is selected as the light source, and Germany FAULHABER brushless dc servo motor is selected to drive polygon mirror, and photomultiplier tubes(PMT) is selected as the detector, and oscilloscope is selected to receive the output signal, see Fig.5.

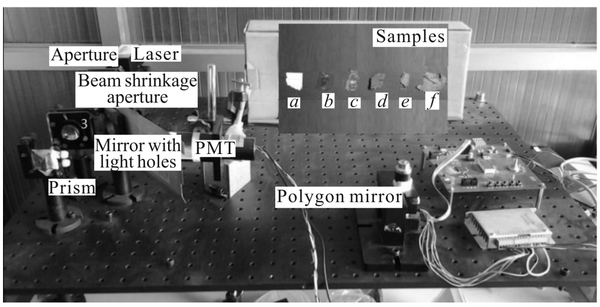

Fig.5 Real light path of system

In this test, the products is excitated with a 665 nm laser beam and the intensity of the reflected intensity should be looked to. This is illustrated in Fig.6 where the reflected intensity of white paper (a), glass sheet (b), plastic film(c), stone(d), tree bark(e) and tobacco leaf(f) are compared. White paper absorb only a small part of the incident light and shows a high reflected signal(a') on the detector; tobacco leaf absorb moderate part of the incident light and shows a moderate reflected signal (f') on the detector. Other foreign bodies strongly absorb the red light and show a low signal (glass sheet (b'), plastic film (c'), stone (d'), tree bark (e')) on the detector. With this technique both products and foreign bodies can be identified.

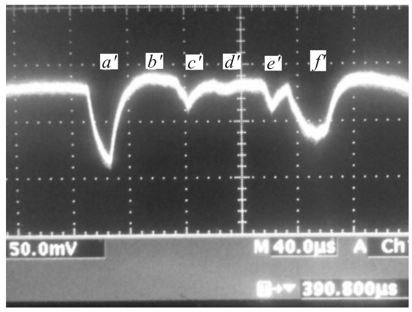

Fig.6 Reflected intensity of tobacco leaf and foreign objects

3.2 Imaging test

Imaging ability of system has been tested in this test. Project requires that the distinguishing ability reach to 2 mm/pixel. Our tests achieve 1.5 mm/pixel, which is higher than the project requirements. The light path is shown in Fig.5. Light source is the laser used in the previous test. The headline in the newspaper is selected as the testing sample, see Fig.7(a). The diameter of scanning spot is adjusted close to 0.35 mm. The laser scans the first line of the picture. Then the picture will be rose 0.35 mm after sampling, that will be repeat 43 times.

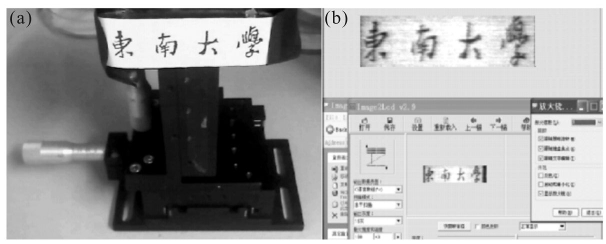

Fig.7 Original image and composite image

The scanning data recorded through computer program is imaged by software. The gray image is shown in Fig.7(b). The resolution of the image is 180*43 pixel. Imaging results illustrate that although the text is not clear enough, obvious defects (1.5 mm) can be recognized accurately.

4 Improvement

From the results, a phenomenon can be found that part of the flux is lost due to the non-perpendicular illumination of the products [7]. Only at the center of the scanning line the illumination beam is perpendicular with the scanning line. The edge of the gray image shown in Fig.7(b) is exposed insufficiently.

As a possible solution to this, the sorting system is improved (see Fig.8).

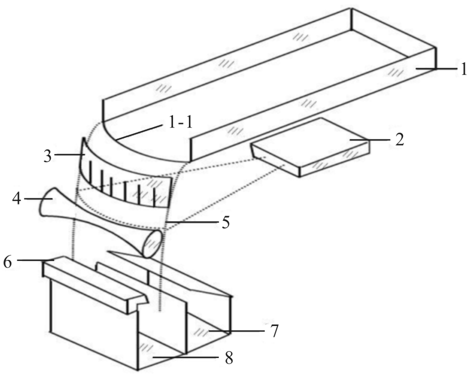

Fig.8 Improved sorting system

The sorting apparatus is shown in Fig.8, products are routed by the vibrating table 1 to the transport device 3 with a downward sloping surface 1-1, on which they come up with a speed having a certain horizontal component. The surface 1–1 and the transporting device 3 have the same curvature which is almost a circular arc.

The detection system 2 can also interact with a reference device 4, generating one or more laser beam that move rapidly over the width of the product stream 5, thereby examining whether foreign bodies or low-quality products 7 are contained in the product stream. If such a body or product 7 is detected, a signal is passed to compressed air device 6, which subsequently blows said body or product 7 out of the product stream, by activating one or more compressed air valves 6 at the correct moment. It is therefore important that each of the bodies or products, located opposite the detection system 2 and the compressed air device 6, all follow paths congruent to each other. The products stream 5 preferably have a constant, or almost constant, speed curve in the zone between the detection system 2 and the removal system 6.

Thanks to the optical system, the distance between two successive scanning positions is constant over the entire scanning line, and the dis tance between the scanning position and the polygon facet is constant, and the illumination angles (here the shape of the products plays a role) are perpendicular.

5 Conclusions

Firstly, a laser sorting system is designed based on the selective absorption principle. Secondly, a high-speed signal sampling experiment and a imaging experiment for the system is tested. By the selective absorption sorting technology, both products and foreign bodies can be identified in the signal sampling experiment. The resolution of the imaging experiment is 180*43 pixel. Imaging results illustrate that although the text is not clear enough, obvious defects(1.5 mm) can be recognized accurately. Finally, after optical scanning system is analyzed, the phenomenon is found that most of the flux is lost due to the non-perpendicular illumination of the sample. A curve scanning sorting structure is proposed for improving sorting machine.

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