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An automatic inspection system for the coating quality of the edge of mirror elements

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ABSTRACT

This study aims to inspect the common defects of the edge of the mirror elements, including scratches, impurities, and edge serration, which occur in the production of mirror elements, where a mirror surface was illuminated in different directions in the experiment. The imaging system was used to inspect the defect position, enhance image contrast, and judge whether the defect exceeds the permissible range. With a novel algorithm, the image contour was analyzed by edge detection, and combined with edge evaluating parameters to improve the quality of the coating edge. According to the experimental results, the proposed algorithm has an average recognition rate of 96% and the recognition speed on a mirror element sized 10×7 cm is only 0.1 s.

1. Introduction

In the production process of the mirror element, the substrate is cut to the required size, ground and cleaned, the required shape is baked, and then cleaned and coated. However, there may be defects in the glass, such as stains, scratches, and cracked edges, during cutting, baking, coating, and transportation.

Mirror defect detection is likely to be disturbed by surface reflection or dust, resulting in deviation of the image captured by CCD. Therefore, it is washed or wiped before inspection in order to reduce the influence of dust. The granular points, bright spots, and chain mark defects can be found in the optical panels or optical module due to color, direction, and gradient features [1–3]. The CCD can be mounted on an optical elements production line to inspect the products images from different angles in order to judge defects [4–6]. The glass panel surface defects and bubbles in the object can be inspected by using machine vision to rapidly inspect defects. The machine vision technology is very suitable to inspect the gray level image of optical panels to judge defects [7,8].

The influence of light source is very important during signal processing [9]. The CCD captures different images for different light sources [10]. Therefore, lighting is the most direct preprocessing means, where image features [11–15] can be effectively extracted by determining the appropriate combination of positions and directions of a light source, analyte, and camera, including enhancing the object features, reducing noise, enhancing foreground and background contrast, eliminating mirror reflection, and increasing contrast. The mirror element can be used to change the angle of the light source when using CCD,

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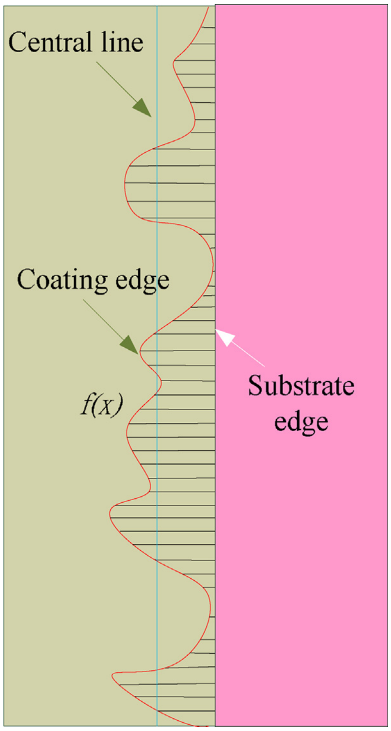

Fig. 1. Average edge stagger factor (Sa).

in order that the light source uniformly illuminated analyte with an irregular surface, which was processed to judge defects. For example, Valle et al. [3] used a curved mirror to change the light source angle in order that the curved analyte received uniform light, and the CCD captured the image surface defect. Fung et al. [1] used graphic control, and CCD to record the image of LED lighting, and judge whether the brightness of LED met the goal. Yang et al. [4] used a microscope to observe the laser focus on the micromodule, and inspected the micromodule contouring in the production line. Zhang et al. [7] improved the multiscale wavelet edge detection method, as based on Canny rules for detecting image edge. Zhang et al. [8] proposed the gradient corrected edge detection method, calculated the absolute difference from large to small pixels of adjacent pixel ranges, and analyzed the distribution of probable edges to estimate the accurate edge [16–18]. Wang et al. used the slope of the root mean square to evaluate mid-spatial frequency mirror surface errors for larger aperture mirrors [19]. Miroslav et al. performed non-contact measurement of concave-mirrors shape, objectively defined the shape, and specified the difference of the segment shape [20].

This study used CCD to inspect mirror element images. The defect position was analyzed by CCD, and highlighted by image processing. The defect in the edge of the mirror element was judged according to the features after image processing.

2. Edge evaluating parameters and uniformity

The image captured may be influenced by dust or particles in the environment, resulting in non-uniform optical field intensity, meaning that the image has many noises influencing subsequent processing. In order to reduce the interference and improve the required information of the image, the captured image shall be filtered [21]. Micro defects are filtered during noise canceling, thus, the permissible range of a product is considered during noise filtering.

According to the relationships between one point and adjacent points in eight directions, the omitted point or isolated point is defined, and the omitted point or isolated point fills or removes micro noise. In a two-dimensional image, the edge is detected by the local maximum of the following equation.

The edge images of objects were captured by instrument. These edge images had many irregularities, magnified to obtain the edge contour. In the edge contour curve, the edge of sputtering was incomplete, and the design edge had many irregularities. The deviation from the substrate edge line was called the stagger factor in this study. The integrity of the edge was determined by calculating the stagger factors. The mirror parts and components from the coating to the edge were used as samples in the experiment. The substrate reference line was used if the coating edge was not the substrate. This study used the following stagger factors for calculation: average edge stagger, number of wave crests, maximum distance stagger, 10-point average stagger, and square root stagger.