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A denoising method based on multiple-stage acousto-optic tunable filter in the green laser measurement system

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ABSTRACT

The charge handling capacity of CCD camera is limited, so image distortion is caused by bright light generated by the hot workpiece. The green laser stripe captured by CCD camera is fuzzy in the green laser measurement system. In order to make the image of the stripe clearer, the filter system is designed based on multiple-stage acousto-optic tunable filter. In the filter system, a computational model is built by combining the visible radiation character of hot workpiece and the threshold power density of CCD saturation. The curve of the filtering rate of bright light can be obtained using the computational model. In order to realize the goal of intelligent filter, each stage of the acousto-optic tunable filter is adjusted according to the curve of the filtering rate. Finally, the image of green laser stripe on hot workpiece is clearer. The filter system designed in the paper is viable according to the experiment results. And the accuracy of the green laser measurement system is improved.

1. Introduction

For the green laser measurement system, the clear green laser stripe is necessary for improving the measurement accuracy. In the past decades, a lot of researches have been conducted by domestic and foreign scholars. Images of hot workpiece are dealt with by Zhao Zhuan-ping through the image processing technology, such as selective filter, image enhancement and smoothing. Then the influence of part of ambient light on the image clarity of the green laser stripe is removed [1–3]. The influence of red thermal radiation on the image clarity is overcome by Liu Gui-hua using the combination of digital filter technology and physical filter technology [4,5]. The edge values of the object are obtained by Dr. Shiuh-Jer Huang using the image processing procedures [6–8]. These methods are proposed from the point of image. The following methods are from the point of the course of image acquisition. The spectrum selective method is proposed by Jia Zhen-yuan. The self-emitted radiation character and reflection character of hot workpiece are analyzed. The light intensity is supplemented by the illumination lamp to acquire images of hot workpiece. Using this method, radiation light captured by CCD is removed [9–11]. A free-electron model of metal is adopted by Ke Wei-na. By using the model, the metal surface irradiated with green laser is simulated. The impact of angle of incidence on metal absorption rate is presented [12]. Bulygin and Kovalev measure the quality of laser beams by methods of fourier optics. The quality of laser beams is improved by a Fourier transform [13–16]. The influence of angle of incidence, object color and measuring distance on the laser scanning process in computer are analyzed by Nikola Vukašinović and Drago Bračun [17]. Thereby it is necessary to find a more effective solution to the fuzzy green laser stripe for the green laser measurement system.

The filter system is designed to make the image of the green laser stripe clearer on hot workpiece. In the filter system, the computational model is built by combining the visible radiation character of hot workpiece and the

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threshold power density of CCD saturation. The curve of filtering rate of bright light is obtained by using the computational model. According to the curve of the filtering rate, each stage of the acousto-optic tunable filter is adjusted by changing the radio frequency (RF) signal and the ultrasonic power. Finally, the image of green laser stripe on hot workpiece is made clearer. And the accuracy of the green laser measurement system is improved.

2. The green laser measurement system

The diagram of the measuring principle is shown in Fig. 1. The green laser device is installed on the linear guide rail, and the device is moved by the servo motor. Firstly, the green laser device is moved to the left edge of the hot workpiece, and the location of the device is recorded by the control computer. Then the green laser device is moved to the right edge of the hot workpiece, and the location of the device is recorded by the control computer too. Finally, the measurement data of the length of the hot workpiece is displayed through the control computer processing. But the image of green laser stripe on hot workpiece is fuzzy. The fuzzy stripe results in the low measurement accuracy. In order to improve the measurement accuracy, the filter system is designed.

The filter system is mainly composed of five parts such as the temperature measuring device, the laser device, the multiple-stage acousto-optic tunable filter, CCD and the control computer. The filter system is shown in Fig. 2.

Firstly, the temperature of the hot workpiece is measured by the temperature measuring device and is received by the control computer. The temperature value is input to the computational model. Then the curve of filtering rate of bright light is obtained. Each stage of the acousto-optic tunable filter is adjusted according to the curve. Finally, the light is received by CCD camera, after it goes through the filter system. And the clear image of green laser stripe on hot workpiece is obtained.

3. The system principle of multiple-stage acousto-optic tunable filter

3.1. The way of obtaining the curve of filtering rate

The curve of filtering rate of bright light is the precondition of working well for the filter system. The curve of filtering rate is obtained by combining the visible radiation character of hot workpiece and the threshold power density of CCD saturation. According to the curve of filtering rate, the visible radiation that causes image distortion is removed.

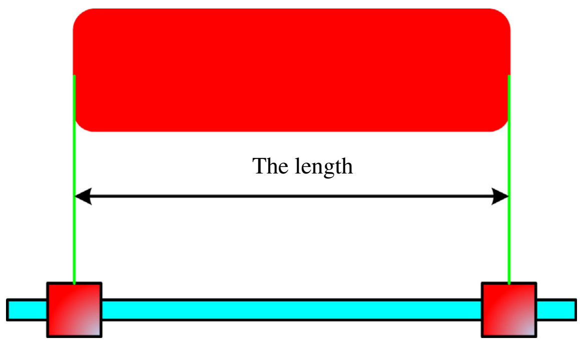

Fig. 1. Schematic of the green laser measurement system.

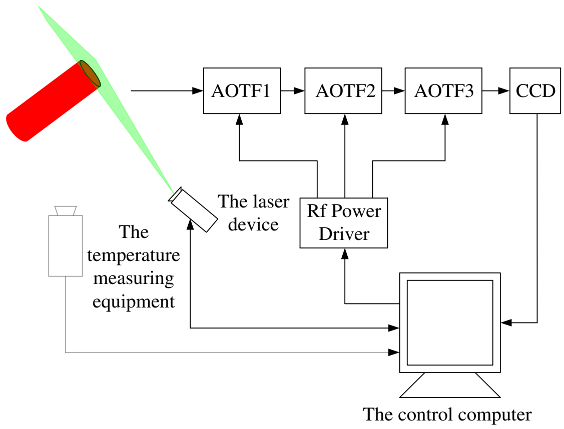

Fig. 2. The schematic of the filter system.

3.1.1. The visible radiation character of hot workpiece

While the hot workpiece is captured by CCD camera, the temperature of the hot workpiece can reach 1200 °C. The visible radiation of hot workpiece is very strong. The image of the green laser stripe is fuzzy. It is necessary to obtain the visible radiation character of hot workpiece for making the image of the stripe clearer.

According to Planck radiation law, the visible radiation character of hot workpiece is connected with temperature of hot workpiece. Eq. (1) is Planck radiation law:

$$M_\lambda(\lambda, T) = c_1 \cdot \frac{\lambda^{-5}}{\exp(c_2/\lambda T) - 1} \tag{1}$$

where c_1 is the first radiation constant, and c_2 is the second radiation constant. c_1 and c_2 can be written as:

$$c_1 = 2\pi c^2 h = (3.741832 \pm 0.000020) \times 10^{-10}\ \mathrm{W\ m^2} \tag{2}$$

$$c_2 = ch/k = (1.438786 \pm 0.000045) \times 10^{-2}\ \mathrm{m\ K} \tag{3}$$

where h is the Planck Constant, k is the boltzmann constant, and c is the velocity of light. h, k and c can be written as:

$$h = (6.626176 \pm 0.000036) \times 10^{-34}\ \mathrm{J/K}$$
$$k = (1.380662 \pm 0.000044) \times 10^{-23}\ \mathrm{J/K}$$
$$c = 3 \times 10^8\ \mathrm{m/s}$$

While the hot workpiece is forged, the temperature range of the hot workpiece is 700–1200 °C. So there are 3 temperature values (800 °C, 1000 °C and 1200 °C) of hot workpiece chosen to be researched. The values of the temperature are respectively substituted into Eq. (1). Then the curves of the visible radiation character under different temperature are obtained, and the curves are shown in Fig. 3.