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Research on the Measurement System of Large Dimension Workpieces Based on the Technology of CCD and Laser

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Abstract. A kind of the measurement technique of the dimension and the geometry error of large dimension workpiece with two light routes and two CCD sensors has been made. The mathematical models of the dimension and the geometry error based on the technology of CCD and laser are established. The application property parameter to measure workpiece dimension and geometry error and the design characteristic related supplemental hardware of CCD sensor are studied. An on-line data collection system based on laser and liner array CCD is developed. This systematic C8051 single-chip microcomputer as controler that adopt American CYGNAL company's production carry out handling and the collection of data. the system meets the measurement requirement of no-touch, on line and high precision with adopting of machine, laser and electricity comprehensive technology. The result can be got in this paper: the CCD sensor can meet the need of measuring dimension and geometry error of big workpiece and is no-touch, on line measurement and high precision. The on line collecting data system can achieve the expecting function, and measure data on line, and it also can easily connect with auto control apparatus.

Introduction

What existing CCD length dimension measure system is adopted normally the technology that parallel light forms an image. When a bundle of parallel light is shot in the goal to be measured, the shadow of goal becomes picture on CCD sensor via optical system. From the two edge locations of an image of goal, can get the dimension of an image.

This measure technics has ripened very much. In measuring sliver diameter, the width of silk ribbon and wire diameter etc., this technical application is fairly extensive. because of length restriction of CCD sensor's sensitization element, this measurement technique can not realize the measure of greater dimension. The detection method of traditional big dimension is measured mostly with manpower work, For example caliber , π ruler etc. The traditional measurement could not suit the requirement of development, because the traditional method has so many disadvantages, such as low efficiency , low precision etc. A kind of measurement technique that measures big workpiece dimension and geometry errowith two smooth road and two CCD sensors has been made and The CCD sensor's capability in dimension measurement has been discussed in this paper. It is the basic theory for designing the system of online large dimension workpiece measurement.

The Measuring Principle and the Mathematical Models of Dimension and Geometric Error

The principle of the workpiece dimension and geometry error measuring system with two light routes and two CCD sensors show as Fig.1. The parallel light that laser shoots on workpiece, CCD sensor take over laser. L_1 can be determined through the distance between two laser， the length that sheltered from by workpiece on CCD chip can be got through counting by single-chip microcomputer. So the dimension of the workpiece is $L_1 + L_2 + L$.

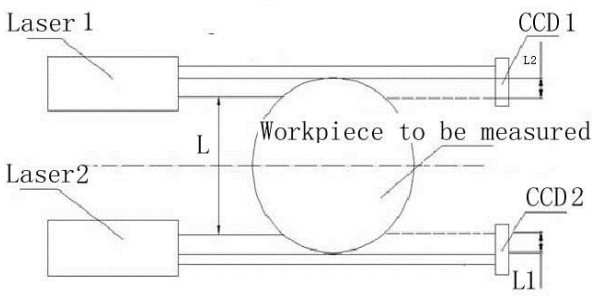

Fig. 1 The principle of the measuring system using two light routes

$$\begin{cases} L_{1i} = \Delta L_i + L_{10} + e_i \\ L_{2i} = \Delta L_i + V_{20} + e_i \end{cases} \tag{1}$$

Where ΔL_i is radius deviation of the measured section corresponding to point P_i, L_{10}, L_{20} the initial values of CCD sensors L_1 and L_2, and e_i the rotating radial system error of the principal axis of point P_i.

Make probes L_{1i} and L_{2i} sample the data synchronously. The sample points of the measured section locate in the same interval of angle and are expressed as points P_i $(i = 1,2.\cdots,m)$, where m is the number of the sample points and m is even. After rotating radial errors of principle axis have been separated, the roundness error's radius increments of the sample points can be computed with the following formula:

$$\begin{cases} \Delta L_i = \dfrac{1}{2}(L_{1i} + L_{2(i+\frac{m}{2})}), & 1 \le i \le \dfrac{m}{2} \\ \Delta L_i = \dfrac{1}{2}(L_{1i} + L_{2(i-\frac{m}{2})}), & \dfrac{m}{2} \le i \le m \end{cases} \tag{2}$$

Let θ_i be the angle of the sample point, and $\theta_i = \dfrac{2\pi}{m}(i-1)$,($i = 1,2,\cdots,m$). Let ε_i be the deviation of the sample point relative to the least square round along its radius. ε_i can be described as[5]:

$\varepsilon_i = L_i - L - a\cos\theta_i - b\sin\theta_i \quad , i = 1,2,\cdots,m$

Where $a = e\cos\alpha$, $b = e\sin\alpha$ which describe the location of the centre of the least square round, and the following formula are founded:

$$\begin{cases} L_i = L_0 + \dfrac{1}{m}\sum \Delta L_i, \\ a = \dfrac{2}{m}\sum_{i=1}^{m} \Delta L_i \cos\theta_i \\ b = \dfrac{2}{m}\sum_{i=1}^{m} \Delta L_i \sin\theta_i \end{cases} \qquad i = 1,2,\cdots,m \tag{3}$$

The roundness error is:

$$f_{\mathrm{O}} = \max\{\varepsilon_i\} - \min\{\varepsilon_i\}, \ i = 1,2,\cdots,m \tag{4}$$

The Requirement and Application Characteristic of CCD in Dimension and Geometric Error

As a type of micro graphic sensor, CCD have both the function of photoelectric and holding， transfer and reading. It can transfer a spatial domain distributing picture to electric signal of time domain separation discrete distribution in-line

With all kinds of types of CCD, it detection range is related directly with dot array element, and the measuring range is proportional to dot array element and the measuring accuracy. The type of this design is TCD1208AP whose characteristics are:

(1) The number of sensitization picture is 2160;

(2) The dimension of every sensitization element is 14 μ m×14 μ m;

(3) The sensitive region of picture is high sensitive and low undercurrent;

(4) The clock is quarter-phase (5V);

(5) The pin is dual-in-line with 22.

The complex CPLD produce drive signal — such as sync pulse SP and horizontal synchronizing pulse FC, CCD drive work from input to output, CCD's output signal is analog signal $U_0^{'}$. Passing the CPLD pin, we can setup frequency and period of SP and FC

The Requirement of Light Source. Light source is the important part of CCD application technique. So chose a good light source is the important segment of CCD application technique. Considering the most disadvantage of general light source is the light dissipating easily and collimating of light is not enough. In addition considering the mechanism structure and the require of CCD to light, this system adopted laser as CCD light source. The light from laser had different wavelength and different color. Choosing wavelength of laser was 0.635 μ m, generating red laser diode, which wavelength was near to CCD peak value response wavelength. To preventing disturb from other light, we fixed light filter in front of CCD photosurface to strain light with other wavelength, assuring incept efficiency light signal.

CCD output signal was $U_0^{'}$ amplitude value and was related with the corresponding photo element, the light amplitude value was bigger. But it couldn't exceed 5V, otherwise regarded saturation.

Laser Collimating of Light Extender Theory. CCD length size measuring system adopted parallel light imaging method. As a branch of parallel light irradiating a waiting goal, which shadow pass through optics system imaging on CCD sensor. Output signal of CCD adjusted dealing with filtering and magnifying was compared with a fixed threshold value to generate two-valued signal. Numbering two-valued signal could generate the position of aiming two edge. We could generate imaging size from the position of edge. The real size of aiming was imaging size pulse coefficient decided by optics coefficient.

Laser optics was different from normal optics. Laser was spread as Guass. At the transmission direction to laser, beam of light section size increasing was change with hyperbola rule.

This system adopted Keplerian system. In extender lens system middle focusing dot adding one small hole diaphragm, to restrict size of focusing dot. Beam of light of laser bundle was Gauss light distribution. Light distribution on lens focus was Gauss light distribution too. Laser which was extended not only generated paralleling light which parallel to ray axis, but also generated paralleling light with different inclination. So we needed to add small hole diaphragm to filter light with no use.

Output Signal Magnify and CCD Two-valued Circuit Design. Output signal of CCD sensor was weak charge signal, needed magnify generating and edge of charge signal could generate distinctness level change. To extract image information to process information, signal magnify and two-valued process were adopted commonly. Background image information was separated from CCD signal.

To satisfy the require of chip microcomputer collecting signal, $U_0^{'}$ must be transformed digital signal U_0.

Describing of Driver Time Sequence. Horizontal pulse FC rising edge corresponding to the beginning of CCD effective video frequency signal output.(front-end of linear array CCD output contained some invalid signal of line element)The time between two adjacent FC was actual integral time. The rising edge of imaging element sync pulse (SP) was corresponding to video frequency of single imaging element. The output signal was sampled on the rising edge of imaging element sync pulse (SP). The sequential relationship of horizontal pulse(FC)， imaging element sync pulse (SP), output analog signal $U_0^{'}$ and two-valued digital signal U_0 was showed in Fig. 2.

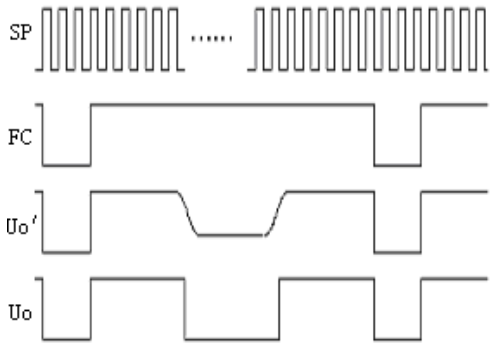

Fig. 2 CCD Input and Output Signal

Design of Data Acquisition System

Detection device of size and geometric sense error needed to be measured of measured sectional dimension. We used two analog voltage comparator integrated by C8051F005 chip microcomputers，two external interrupt and two external counter to collect two CCD output data on the direction of two vertical direction.

Experiment and Conclusion

We carry through dynamic measuring experiment to some cylinder part calibrated already. We collected 64 data in one turn range, ten times collecting totally. So we got ten groups data, then calculating standard deviation adopting Bessel equation. And then we could confirm dispersion range of measuring data. And the result to the experiment, in 99.73% fiducial probability, limiting deviation was not bigger than 0.020mm.

The conclusion of the experiment: detecting element whose size and geometric sense error was CCD sensor, which could realize the require of no-touch， on line and higher precision; on line data acquisition system of this article could realize preplanned function, and also realize no-touch on line dynamic measuring, and it also can easily connect with auto control apparatus.

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