

Development of Open Mode Digital Radiographic Testing System

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Abstract: -The open mode digital radiographic system based on the scintillation conversion screen and scientific grade CCD camera applies wide range radial energy and can be obtained high quality image. The composing and main technical requires are introduced. Author designs the structure of scintillation screen, the spectral characteristic of scintillation screen is introduced, CCD is chosen and its parameter characteristics are introduced, image data parallel acquisition scheme by remote computer are designed. The light route system is designed, the experimental result at low and high energy of X-ray of the system developed by author is given.

Key-words:- open mode digital radiographic, X ray imaging, scientific grade CCD, enhance parallel port, spatial resolution; scintillation

1 Introduction

The non-film X-ray imaging testing is new technique and the development direction of X-ray non-destructive testing. The comparatively more mature means is the X-ray TV system or digital imaging system composed by X-ray intensifier and video camera. This kind of system can obtain image real time. Yet merely be applicable to low energy X-ray. Under 450kV. And the image quality is not good. As to the examination of requiring high quality image and high energy X-ray and γ ray testing, radiography use film is adopted universally. Writer develops a high performance digital radiographic system that applies to high and low energy X-ray and γ ray examination.

2 Scheme and Main Performance Requirements of open mode Digital Radiographic Imaging Testing

The digital radiographic testing system developed by author can apply high and low energy X-ray. Under 15 MeV. With γ ray, it can obtain high

quality image than X-ray intensifier system.

Demands of this system as follows

- (1) The imaging screen diameter $D \geq 150\text{mm}$
- (2) Optimal spatial resolution $\geq 30\text{lp/cm}$
- (3) Image grey grade $\geq 10\text{bit}$
- (4) Image transmission distance $\geq 25\text{m}$
- (5) Systematic penetrable sensitivity $\leq 2\%$
- (6) acceptable X-ray energy $\leq 15\text{MeV}$.

In order to attain high quality image, the digital radiographic testing system based on the crystal scintillation screen and scientific grade CCD camera is developed by author. Fig.1 is the system compose of the digital radiography. First of all the conversion screen convert the rays through the object to the visible light image, and the image brightness is low. long time exposure using the scientific grade of the high performance CCD camera to form image. The image signal is output by driving circuit, converted digital signal by A/D, and data acquisition, process and storage by computer that is in 30m place. The aim of 45° reflector is reflecting the visible light image in CCD camera. And the ray that through the conversion screens can pass the reflector directly. in this way, it can avoid to injury the camera and cause image noise. This has been testified by experiment.

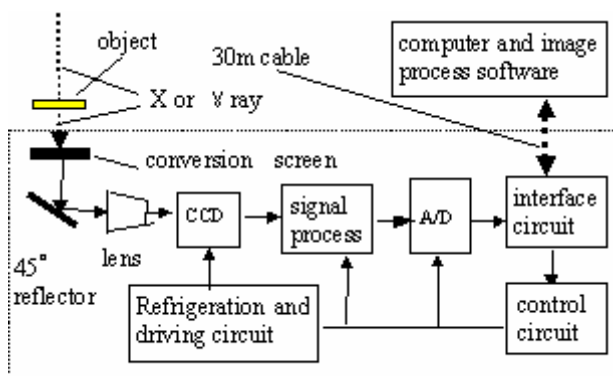


Fig.1 Composing of open mode testing system

3 The Characteristics and Selection of Scintillation Screen

The radial conversion screen adopts the scintillation crystal, that chief parameters such as the luminous

efficacy, Emission spectrum, Hardness,

Parameter	unit	min	typ.	Max.
Saturation signal	V	0.4	0.7	
Full well	Ke ⁻		130	
Optical response	%		1.5	2.5
non-uniformity	e ⁻ /s		20	
Dark signa			1×10 ⁻⁵	3×10 ⁻⁵
Charge transfer inefficiency				
Readout noise	e ⁻		10	15
Quantum efficiency 250nm	%		20	
400nm	%		35	
700nm	%		55	
1000nm	%		8	

deliquescence property and so on. NaI(Tl), CsI(Tl), CsI(Na) □ CdWO4, BGO □ LII(Eu) are primary scintillation crystal.

On the point of practice use, we wish the scintillation screen area big □ not deliquescence □ high luminous efficacy □ spectrum matched with CCD □ and the physical and chemic performance is steady □ conveniently to use and to conserve.

By compare □ according to the testing demands □ Finally CsI(Tl) crystal is chosen □ Fig.2. is the structure of conversion screen produced by

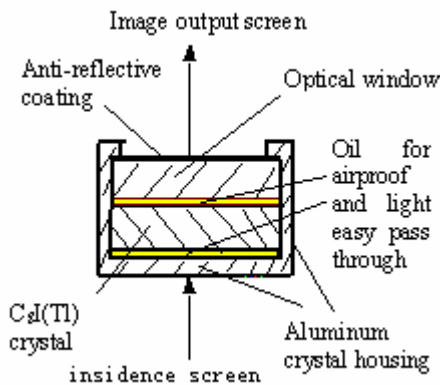


Fig.2 structure of conversion screen

BICRON.

Because CsI(Tl) is pliable and slight deliquescence in the air, so we have to seal it .For obtaining the distinct image □ the black aluminous housing that can suck light is sued to safeguard and to fix the entire conversion screen. Optics glass window is safeguarded the crystal □ The oil layers have functions of airproof And helping scintillation light to pass the interface of two different medium □ reducing reflection □ The function of anti-reflective coating is used to reduce reflection of image .

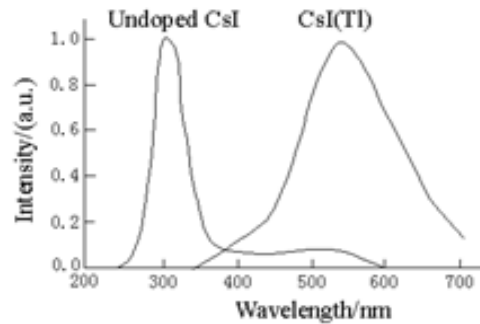


Fig.3 Spectrum response of CsI Tl

Fig.3 is spectrum response of CsI (Tl) crystal and undoped CsI pure CsI □ crystal. It is visible that the spectrum of CsI (Tl) crystal is wide than pure CsI crystal □ And being close to man's spectrum response curve. The light output performance of CsI (Tl) crystal is steady in normal environment □ The peak wavelength is 550nm □ The main energy wavelength is in the range of 400nm □ 700nm.

4 Development of Scientific Grade CCD Camera and Its Image Data Acquisition Circuits

Because the image brightness output from conversion screen is very low, the scientific CCD camera that has large dynamic range , low dark current , low Optical response non-uniformity and low noise is used to obtain high quality image by long time exposing.

The CCD chip is chosen, its driving circuits, refrigeration circuit and control circuits of signal process and data acquisition circuit are designed.

4.1 The selection of CCD and ISD017AP type CCD briefly introduction

The diameter of testing area is 150mm □ The spatial resolution is 3lp/mm □ Therefore the CCD pixels number at least demand 900 ×900, Consider remaining surplus, t the valid pixels of CCD had better be more than 1K ×1K □ Consider price , optics performance and marketplace □ the ISD017AP type CCD produced by Russia is chosen , below table is parameter characteristics of ISD017AP type CCD.

Tab.1 the main parameter of ISD017AP CCD

ISD017AP type CCD has 1160 ×1040 pixels, the size of pixel is 16 μm×16μm. It has 1094 readout registers □ 1040 are valid □ □ Fixing platinum resistance sensor on the chip to measure CCD

temperature placing Peltier cooler on the CCD use to refrigerate to CCD. It has characteristics of refrigeration easy and high ratio of performance.

4.2 The scheme of image readout and data acquisition

It is the important section of image capturing that the driving circuits and data acquisition circuits its function is to produce the sequence signal of CCD readout under the computer control and to transforms each pixel charge signal into voltage signal, after the circuit process, to convert analog signal to digital signal, to read the data into computer that is distant from CCD. Fig.4 is the functional block diagram of data acquisition. Semiconductor sensor can measure the temperature of CCD, its value can control the semiconductor cooler, refrigeration circuit guarantee the CCD working at the environment below 30.

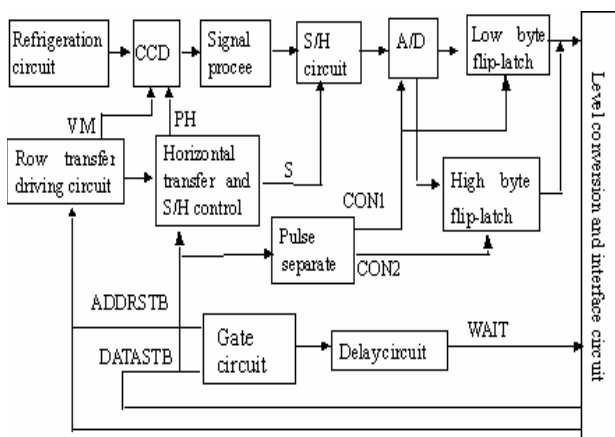


Fig.4 Scheme of data acquisition and CCD camera

4.3 The pipeline mode of CCD charge readout, A/D conversion, data transmission

After analyzing the driving sequence demand of CCD for the sake of the circuit is easy the image data pipeline acquisition method using EPP mode of computer is designed. (CCD signal readout, 12 bit A/D conversion and data transfer distance process at the same time controlling by one EPP readout signal. However 3rd data transfer into computer is the value of 1st pixel the rest may be deduced by analogy).

The main work process is at the action of EPP address read signal ADDRSTB, The hardware circuit designed by author produces row transfer driving signal VM VM1 VM2 at the action of EPP data read signal DATASTB, The hardware circuit produce horizontal transfer driving signal PH PH1 PH2 RG and control signal of S/H at same time produce start signal CON1 of A/D convertor, start to convert the

signal that is readout last time hold in S/H, and produce transfer control signal CON1 and CON2 that can read the data into computer, the data is the signal readout before last time converted by 12 bit ADC temporary storage data in flip-latch.

Besides the CCD camera parts from the computer about 30 meters This is different with ordinary image acquisition by PCI image acquisition board in short distance. thus author adopts high speed TTL RS422 difference driving and receive circuits to realize data Parallel transfer at long distance.

5 Design of Light Route

The task of light route system is bring the feeble light image of conversion screen to the CCD. the output image of conversion screen is the circular (150mm) the CCD is square available area is 16.64 x 16.64mm² and the object of Being examined is much kinds of form shapes.

Generally speaking that the imaging mode is circularity within square or square within circularity Separately like Fig.5 (a) and (b).

The Fig.5 (a) strongpoint is testing size large The conversion screen obtain sufficient use for great object It is beneficial to raise examination velocity. The defect of Fig.5(a) is that pixels of CCD can not sufficiently utilize The spatial resolution of image is low Fig.5(b) is beneficial to raise image spatial resolution Yet conversion screen can not sufficiently utilize. What mode is adopted needs synthesize the size of object, the demand of image detail and testing velocity and so on.

Say on theory considering image spatial and testing velocity, The optical system should may be regulated on the basis of the object size.

Because the object is neither circular nor quadrate at most case, for the sake of sufficiently

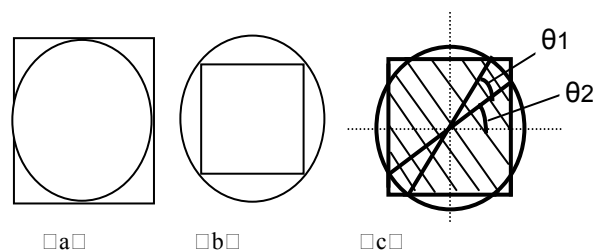


Fig.5 matching relationship of circular image and quadrate CCD

utilizing CCD and conversion screen Choose the maximal generate use ratio of CCD and conversion screen.

Fig.5(d) is match relationship of circular object

and quadrate CCD, Sections on four edges of screen and four horns of CCD are not utilized.

the shade section area is the image area in the picture—suppose CCD margin length is a , image radius is r , image area is S_I

after calculation, when: $r = 0.545a$, viz.

$$\beta = \frac{2r}{D} = \frac{2 \times 0.545 \times 16.64}{150} \approx \frac{1}{8.27}$$

$$\cos \theta_2 = \frac{0.5a}{0.545a} = 0.917, \theta_2 = 23.5^\circ, \text{the general}$$

utilization is maximal. $\eta_{\max} = 0.831$. Screen diameter $D = 150\text{mm}$ —margin length of CCD is 16.64mm . thus, uprightness amplifier ratio is:

Because image of screen output is feeble light image—In order there to be the great light flux—choose large aperture—low distortion standardized camera lens of NIKKIR $F = 50\text{mm}$ AND $F1.2$. According to the β value—The object distance is in $500 \sim 600\text{mm}$ —By means of test—The distance between screen and 45° reflector is 300mm , The reflector is away from lens about 240mm . Experiment proof — by adjusting focus it can obtain legible image of Fig. 5 —c—form.

6 Experiment and Result

On the basis of the above design —author has developed digital radiographic testing system that can apply to low and high energy X-ray and γ ray imaging testing. And has done a great deal experiment and study work. The system attain the design aim. the image obtained by the system obviously is superior to the system consist of X-ray intensifier and video camera—its disadvantage is that imaging time is longer than the real time imaging system —. This system particularly is applicable to the situation requiring the high quality image testing.

Fig.6 is the image of 3rd standard penetrometer that place 5mm thickness steel board obtained under low energy X-ray and image of object obtained under high energy X-ray—not be processed—.

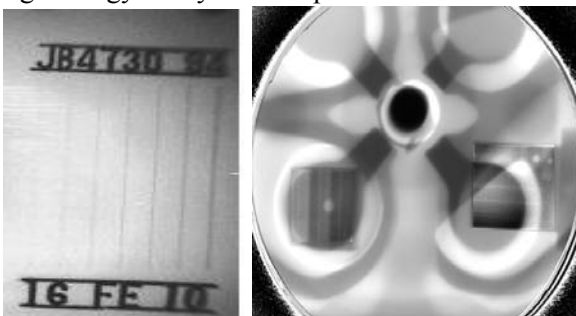


Fig.6 images of penetrometer attach to steel plate and component obtained by the system

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