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Application of X-ray Flaw Detection in Pressure Vessel

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ABSTRACT : *In order to ensure the quality problems of pressure vessels in the application process, it is necessary to detect them before application to check whether there are cracks and other defects.The main detection method is non-destructive testing, which will not cause damage to pressure vessels.As one of the non-destructive testing methods, X-ray flaw detection is widely used.This paper describes the application of radiographic flaw detection technology in pressure vessel inspection, and discusses the influencing factors of imaging and process selection.It plays an active role in promoting the development of pressure vessel radiographic inspection technology.*

KEYWORDS –*pressure vessel steel, X-ray flaw detection; imaging influencing factors; process selection*

I. INTRODUCTION

Since the 21st century, researchers have been exploring and innovating in non-destructive testing and related fields, which make non-destructive testing technology, develop faster and more comprehensively.Non-destructive testing technology is gradually developing towards greening, automation, computerization, integration and intellectualization.The butt joint of two spliced plates is often used in pressure vessel. Therefore, ray detection is often used to evaluate welding quality in industrial production.On the one hand, the negative can be preserved for a long time. On the other hand, the cost of detection can be saved when the hardware conditions are satisfied.X-ray flaw detection is one of the non-destructive testing methods[1].Its X-ray negative image is comprehensive, intuitive, highly recognizable and can truly reflect the actual internal welding situation of the weld.Therefore, X-ray inspection is preferred in non-destructive testing of pressure vessels and pressure pipes.

II. PRINCIPLE OF X-RAY FLAW DETECTION

In The main application of X-ray flaw detection is to detect the macroscopic geometric defects in the specimen.

Assuming Radiation interacts with matter in the process of penetrating an object, and its intensity is weakened by absorption and scattering.The attenuation coefficient of matter and the thickness of rays traveling through matter determine the attenuation degree of intensity[2].If there is a defect in the part of the exposed object (specimen) and the attenuation coefficient of the material constituting the defect is different from that of the specimen, the intensity of transmission rays in the part will be different from that around it.Place film or other imaging devices in appropriate positions to make them image under the action of transmission rays. Because the transmission intensity of defective and intact parts is different, the blackness will appear on the negative or the corresponding parts of the imaging device.The blackness difference between adjacent regions is defined as contrast[3].The principle of imaging detection is that images of different shapes are formed by contrast. .

Quantitative analysis of the variation of ray intensity caused by defects can be made as follows: as shown in Fig.1, a beam of radiation with intensity I_0 passes through the specimen with defects. The thickness of the specimen is T, the attenuation coefficient isμ.

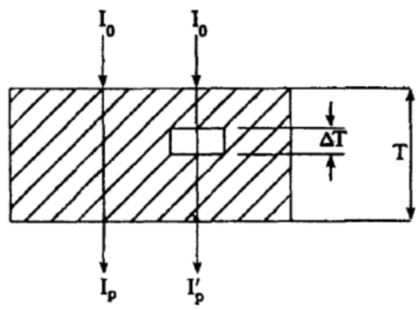

Fig.1 Principles of Radiographic Detection

The first ray intensity through the intact part of the specimen is I_P, the ray intensity through the defective part is I_P’, the total ray intensity through the specimen is I, and the scattering ratio of the specimen is n. It can be seen from the law of ray attenuation that:

$$I = I_0(1+n)e^{-\mu\cdot t} \quad (1)$$

$$I_p = I_0 e^{-\mu\cdot t} \quad (2)$$

$$I_{p'} = I_0 e^{-\mu\cdot(T-\Delta T)} \quad (3)$$

$$\begin{aligned}\Delta I &= I_{P'} - I_P \\ &= I_0[e^{-\mu(T-\Delta T)} - e^{-\mu\cdot t}] \quad (4) \\ &= I_0 e^{-\mu\cdot t}(e^{\mu\Delta T} - 1)\end{aligned}$$

Eq.4 can be divided by Eq.1 as followed:

$$\frac{\Delta I}{I} = \frac{e^{\mu\Delta t} - 1}{1+n} \quad (5)$$

$$e^x \approx 1 + x \quad (6)$$

From approximate Eq.6

$$\frac{\Delta I}{I} = \frac{\mu\cdot\Delta T}{1+n} \quad (7)$$

III. INFLUENCING FACTORS OF RADIOGRAPHIC SENSITIVITY

Sensitivity refers to the degree of difficulty in identifying small defects or small details on the X-ray film, or the smallest defect or the smallest detail size that can be identified on the X-ray film.Sensitivity can be divided into absolute sensitivity and relative sensitivity [4]. There are three main factors affecting the sensitivity of radiography: contrast, clarity and granularity.The sensitivity of X-ray imaging is a comprehensive result of these three factors, as shown in Fig.2.

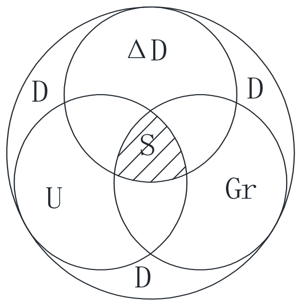

Fig.2Compositionand core of radiographic image quality

3.1. Contrast of X-ray imaging

If the thickness difference exists in the work piece, the intensity of the transmitted rays of different thickness parts will be different after the ray penetrates the work piece. When exposed by this ray, different parts of the negatives processed by darkroom will produce different blacknessShadows on radiographic films are made up of shadows of different darkness. The difference between the darkness of shadows and background enables the image to be observed and recognized[5].The difference of blackness between a small area on a negative and its adjacent area is called film contrast.Generally speaking, the higher the contrast, the easier to identify the defect image is.

The contrast of X-ray film is the result of the common effect of the main factor contrast and film contrast.The principal cause contrast is the fundamental cause of film contrast, and the film contrast can be regarded as the magnification factor of the principal cause contrast, which is usually 3 to 6.

It can be seen from Eq.6 that the main factors affecting the contrast are the transparent thickness, attenuation coefficient and scattering ratio.The contrast formula of X-ray imaging is as follows:

$$\Delta = \frac{0.434\gamma\mu\Delta T}{1+n} \quad (8)$$

3.2. Radiographic clarity

Radiographic sharpness refers to the sharpness of the image edge outline on a radiographic negative.When a beam of radiation passes through a specimen with uneven thickness and forms an image on the negative film, the blackness at the change of thickness does not change abruptly.But it has a transition zone of blackness, so the image outline is not very clear and there is a certain degree of blurring, which is called blurring.Uncertainty consists of two factors: geometric ambiguity and inherent ambiguity.

The Geometric ambiguity, also known as penumbra, is caused by geometric dimensions such as source size, defect location and source, relative position of work piece and film. As shown in Fig. 3, the numerical value of geometric ambiguity can be calculated by Eq.9.

$$U_g = \frac{d_f \cdot b}{F - b} \quad (9)$$

The Geometric ambiguity depends on the size of the source, focal length *F* defect and film distance *B*. The smaller the size of focus, the larger the focal length is, the smaller the distance from defect to film, the smaller the geometric ambiguity is.

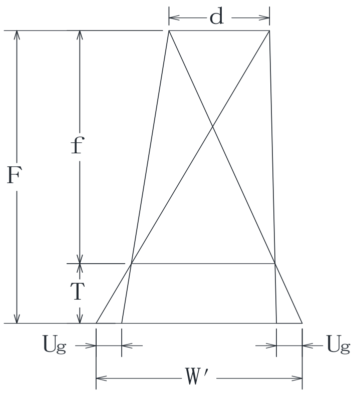

Fig.3 Geometric ambiguity schematic

The inherent ambiguity is due to the scattering of electrons stimulated by radiation on the film in the emulsion layer. When photons pass through the emulsion layer, photoelectric effect, Compton Effect and electron pair effect occur in the interaction with the emulsion, which excites electrons in the emulsion.These electrons scatter in all directions, which sensitizes the silver halide grains in the emulsion to light and forms a latent image [6]. After the film develops, the outline of the image is blurred.The inherent ambiguity depends mainly on the energy of the ray. The greater the energy, the greater the inherent ambiguity is, as shown in Fig.4.

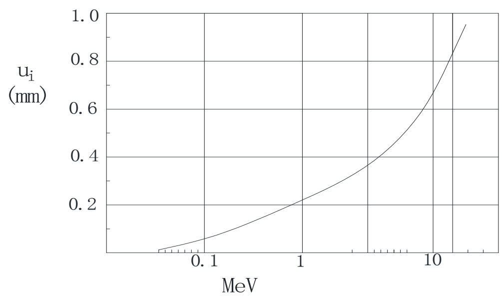

Fig.4 Experimental curves of inherent uncertainty of radiography under different radiation energy

The use of sensitizing screens also increases the inherent ambiguity, especially when the screen is not in good contact.

3.3. X-ray imaging granularity

Granularity refers to the visual impression of uneven distribution of image blackness on a uniformly exposed film.Particularity is the so-called fluctuation value of film blackness obtained by a certain method from the data measured by micro photometer. Granular impressions are not formed by single photosensitive silver grains, but by clusters of silver grains overlapping each other.Particle size limits the minimum size of detail that the image can record.A small detail may not be able to form its own image in the image with larger particle size, or its image may be submerged by the fluctuation of blackness and cannot be recognized.

IV. SELECTION OF RADIATION PROCESSING CONDITIONS

4.1. Selection of Radiation Sources

In the primary factor in choosing the source of radiation is that the radiation emitted by the source has sufficient penetrating force on the tested specimen.For X-rays, the penetration force depends on the tube voltage.The higher the tube voltage, the harder the ray quality, the smaller the attenuation coefficient in the specimen is, and the greater the penetration thickness is.In pressure vessel X-ray inspection, because a lot of X-ray imaging is needed, X-ray is good, so the exposure time is short and the efficiency is high.

4.2. Selection of X-ray energy

The higher the ray energy, the greater the penetration force is.The high energy of X-ray has adverse effects on the contrast and particle size of X-ray photography[7].The principle of choosing ray energy is to have enough penetration force to penetrate the work piece, and to adopt lower energy as far as possible under this premise, as shown in Fig.5.

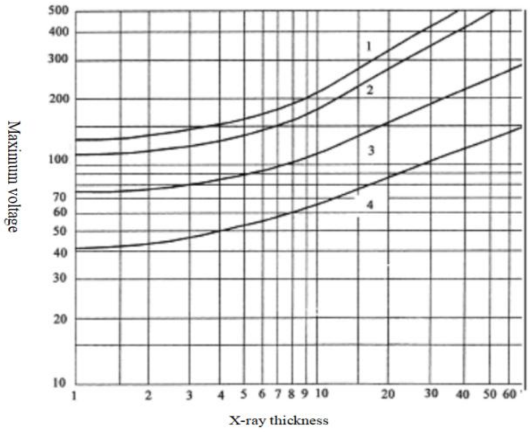

Fig.5 Radiographic Thickness and Maximum Permissible Voltage Curve

4.3. Focal Length Selection

The influence of focal length on imaging sensitivity is mainly manifested in the ambiguity.Eq.3 shows that the larger the focal length, the smaller the geometric ambiguity value.Choosing a smaller size of the emitter can achieve the same effect as increasing the focal length. Therefore, when choosing the focal length in actual radiography, the focus size and the focal length are related factors that are considered simultaneously.However, the focal length should not be too large, because if the image gray level remains unchanged after the focal length increases, the exposure amount or voltage must be increased while the focal length increases[8]. The former will reduce the efficiency, while the latter will have a negative impact on the sensitivity.

The choice of focal length is sometimes related to the geometry of the specimens and the mode of transmission.

V. CONCLUSION

The In the application practice of non-destructive radiographic testing technology, there are still many factors affecting the quality of inspection.Starting from the principle of radiographic flaw detection technology, this paper analyses the application of radiographic flaw detection technology in pressure vessel detection, and then discusses the influencing factors of radiographic imaging and the selection of radiographic flaw detection technology in the application process of radiographic flaw detection technology on the basis of analysis.The research in this paper has an important guiding role in the quality inspection of pressure vessels in industrial production, and is conducive to the better application of radiographic inspection technology in practice.

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