Automatic Fiberboard Density Testing Based on Application of Computed Tomography

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Abstract. Fiberboard has long been a significant practical material. Computed tomography (CT) shows great potential for nondestructive testing of the property and internal structure of fiberboard. In the paper, utilize CT technology in nondestructive testing procedure of fiberboard as well as compute the CT number range of different fiberboard tomography slices in statistic method. Therefore it provides an automatic manipulative procedure in the fiberboard nondestructive testing based on CT. The fitting linear formula between CT number and fiberboard density was calculated, because of the linear relationship exists between fiberboard density and CT number. Thus, a new method in the nondestructive testing of fiberboard defect and fiberboard density is provided.

Keywords: fiberboard, density, CT technology, nondestructive testing, CT number.

1 Introduction

In the recent years, the development of science and technology the level of stuff nondestructive testing technology is higher and higher. The nondestructive technologies are based on the multi-subject and high technology. And in the lab, these testing methods have been applied and tested. Via practice and application, several main nondestructive testing methods were formed. One of the most common used testing methods in them all is radiographic testing. Moreover, in the radiography testing method, X-ray is applied frequently.

X-ray computed tomography (CT) is a branch of radiographic testing method, which uses x-ray as its radiographic source. Computed tomography is being increasingly employed for automated detection and localization of internal defects in logs prior to their scanning [1]. Of all methods, CT has received the greatest profits for industrial log inspection because of its internal imaging capacity, high penetrating power, efficiency and resolution [2]. Obviously, CT is not only fit for the testing of logs, but is suitable for the testing of fiberboards as well. The research in this paper applied CT for fiberboard nondestructive testing.

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In the paper sixteen fiberboard samples were scanned by CT system, the slice images and the CT number of each slice were acquired. Through the statistic method, the range of CT number in each fiberboard sample was calculated.

Fiberboard is a type of engineered wood product that is made out of wood fibers. Types of fiberboard (in order of increasing density) include particle board, medium-density fiberboard, and hardboard. Fiberboard, particularly medium-density fiberboard (MDF), is heavily used in the furniture industry [6].

The density of fiberboard is its most important physical characteristic. Most mechanical properties of fiberboard are closely related to density. Because of the density value affects the in-process quality of fiberboard as well as the usage of it directly. Therefore the testing of fiberboard density is very important in the fiberboard research.

2 Structure of CT System and Imaging Principle

2.1 Basic Imaging Principle of Computed Tomography

Different energy source used by computed tomography as radiation source has different imaging principle. Take X-ray for example, during CT scanning, an X-ray beam passes through the targeted part of the sample by multiple array projection around the sample, and a cross-sectional image or matrix is reformed. Each of these through the sample is composed of an array of pixels (picture elements), which describes the X-ray attenuation coefficient of volume elements (voxels) of the scanned object. The attenuation coefficient can be correlated to the density of the voxel in the certain area of the object. The outputs of the CT scanner are matrices of CT numbers expressed in Hounsfield unit (HU).

X-ray attenuation obeys Beer law [3]. Attenuation diagram of Beer law is shown in Figure 1.

When ray imposes the object, ray intensity is:

$$I = I_0 \exp(-\mu l) \tag{1}$$

When the object is heterogeneous:

$$I = I_0 \exp[-l(\mu_1 + \mu_2 + \cdots + \mu_i)] \tag{2}$$

where I_0 is the initial intensity of ray;

I is the ray intensity after attenuation;

μ_i is ray attenuation parameter of different object;

l is the length of each detected object.

2.2 Structure of CT Scanning System

X-ray CT system has five parts as shown in Fig. 2. They include radiation source, mechanic scanning system, data acquisition system, display and storing system. The CT system composed of two large parts: imaging segment and computer segment.

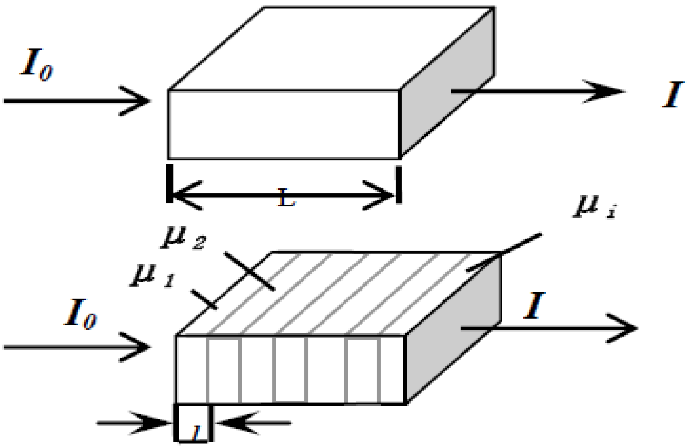

Fig. 1. Attenuation diagram of Beer law

Three radiation sources are commonly used by CT; they are low-energy X-ray source, γ-ray source and high-energy X-ray source. The function of mechanic scanning system is to rotate and translate the detected object while scanning and to adjust the distance and relative position between radiation source, object and detector. Main performance indexes of mechanic scanning system are: scanning mode, shift mode controlling mode and accuracy [4].

The central exponent of data acquisition system is the detector. It receives ray signal, and forms original data of CT system, its performance affects the CT image quality directly.

Using specific software in computer system, parameter adjusting, scanning procedure controlling, data processing, image reconstructing, image displaying and storing can be completed. Its main function is processing and controlling.

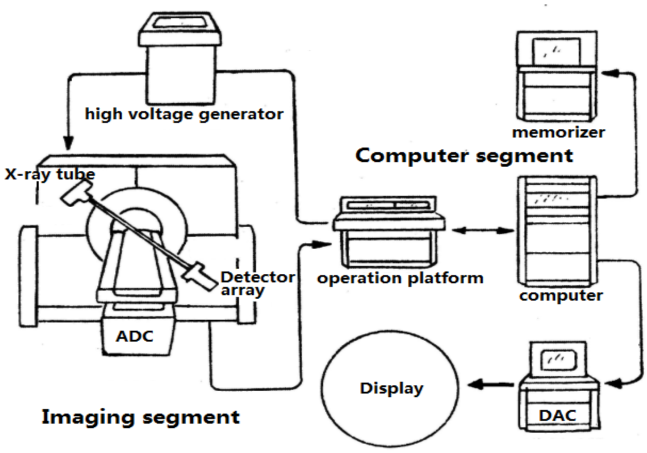

Fig. 2. Structure of CT scanning system

3 Calculation of CT Number to CT Testing

CT number is the value of each pixel in the reconstruction image. It is a relative value in the practice application. The attenuation coefficient of water is served as reference value. The calculation formula of CT number as follow:

$$CT\_number = \frac{\mu_T - \mu_W}{\mu_W} \times k \tag{3}$$

where μ_T is the absorption coefficient of tested object;
μ_W is the absorption coefficient of water;
k is a constant (sometimes k=1000) .

The unit of CT number is Hounsfield units (Hu). Therefore, from the formula the CT number of water is 0. The CT number of vacuum air is -1000.

For the purposes 16 samples from different kinds of fiberboards were selected. 2 slices in each sample and 56 points in each slice were selected. That is, 112 points are selected in one sample. Table 1 shows the partial CT number of 16 samples.

Table 1. Partial CT number (Hu) of 16 samples slices

Sample1	Sample2	…	Sample8	Sample9	…	Sample15	Sample16
-327	-383	…	-414	-420	…	-172	-517
-340	-402	…	-392	-414	…	-191	-516
-339	-406	…	-403	-420	…	-153	-517
-343	-403	…	-432	-427	…	-144	-525
…	…	…	…	…	…	…	…
-354	-403	…	-393	-400	…	-158	-515
-338	-402	…	-415	-402	…	-138	-526
-361	-412	…	-428	-390	…	-110	-512
-360	-431	…	-377	-389	…	-144	-518

4 Fiberboard Density Testing

4.1 Introduction of Fiberboard Density

Density of fiberboard is defined as the mass or weight per unit of volume in the fiberboard. It is usually expressed in grams per cubic centimeter or kilograms per cubic meter. Sometimes it is called specific gravity which is a relative value without the unit. The specific gravity of fiberboard is its one of the most fundamental physical characteristics. Most mechanical properties of fiberboard are closely correlated to specific gravity and density. The strength of fiberboard as well as the stiffness increases with density. The heat transmission characteristics of fiberboard increase with density and the heat per unit volume produced in combustion. The shrinking and swelling behavior of fiberboard is also affected, although the correlation is not as direct as in the case of strength properties. Thus, the density of fiberboard is the first fiberboard property to be investigated scientifically.

4.2 Automatic Testing Method in Fiberboard Density

The volume of the fiberboard may be acquired in many approaches. For one piece of sample that is regular in shape, such as a section of fiberboard, the simplest method is to measure the dimensions as accurately as possible and to calculate the volume.

If the sample is not regular in shape, such as a tree cross section or a fiberboard chip, the volume can be obtained by an immersion or displacement method. This volume can be converted to a volume from the known density of fluid. The immersion procedure chooses pure water as the fluid. Nevertheless, when dry fiberboard sample is immersed, it must be coated with wax or other waterproof material so that water will not penetrate the sample and makes an erroneous low volume determination. Or, an immersion method that avoids the wetting problem with dry samples makes use of a fluid such as mercury that will not wet the fiberboard sample or enter the lumens exposed on the surface.

5 Establishment of Fiberboard Density Formula

There are many different fiberboard density calculation methods. In the paper the fiberboard density is used for calculation, since the density is used frequently in the practice operation. The calculation formula is as follow:

$$\rho_q = \frac{G_q}{V_q} \tag{5}$$

where ρ_q is the fiberboard density, g/cm3,

G_q is the fiberboard mass, g,

V_q is the fiberboard volume, cm3.

Table 2. Fiberboard CT number and relative fiberboard density value. Fiberboard sample density value is used in the calculation, since the fiberboard density is used frequently in the practice operation.

Sample	Sample 1	Sample 2	...	Sample 8	Sample 9	…	Sample 15	Sample 16
CT number (Hu)	-348.5000	-393.9464	…	-400.1696	-409.7500	…	-159.4464	-519.4375
Density (g/cm^3)	0.680	0.616	…	0.596	0.597	…	0.855	0.487

Because of the linear relationship between fiberboard density and CT number the linear fitting formula can be done by comparing with the mean of CT number in the slices with the fiberboard density. To calculate the data in Table 1 with the arithmetic mean method, Table 2 expresses the fiberboard sample's mean of CT number and relative fiberboard density value.

The formula established from the data in Table 2 is:

$$y = 1.081353 + 0.001186 \cdot x \tag{6}$$

where x is the fiberboard CT number, y is the fiberboard density value. The relationship graph is shown in Fig. 3.

With the formula, the fast and automatic fiberboard density testing can be realized in the condition of fiberboard nondestructive testing. Furthermore, if the CT number of the target can be obtained, arbitrary position density can be tested, for example particle board, medium-density fiberboard and hardboard. Much time can be saved by this method in the density testing, because the CT number can be obtained in the CT system directly. Therefore, CT provides a new and convenient way for fiberboard density testing.

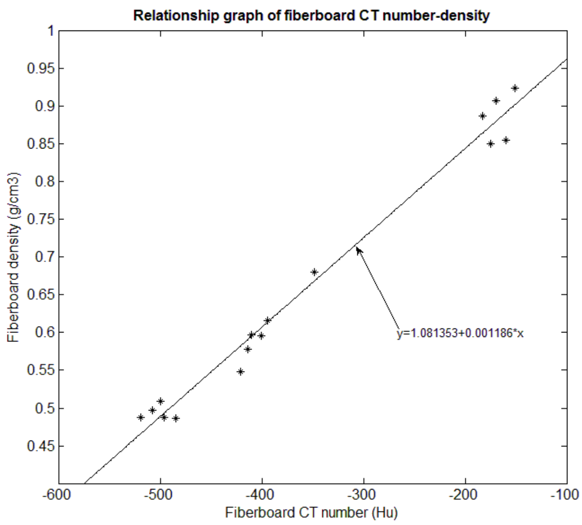

Fig. 3. Fiberboard CT number-density relationship graph. R^2 of fitting formula is = 0.9838.

6 Conclusion

Computed tomography (CT) testing method was selected for fiberboard nondestructive testing after Comparing with conventional radiographic testing. 16 fiberboard samples were scanned by CT system. The slice images and the CT number of each slice were acquired. Through statistic method, the CT number range of each fiberboard sample was calculated. Then, the important parameters of the procedure of fiberboard CT testing; window width and window level were set. Therefore it provides a fast operation procedure in the fiberboard testing method based on CT. Furthermore, compared with conventional fiberboard density testing method, a new method based on CT was provided in the paper. The appropriate linear formula between CT number and fiberboard density was calculated because of the linear relationship between fiberboard density and CT number. Using the formula, much time can be saved in fiberboard density testing as well as selecting formless shape fiberboard sample in the testing. Therefore it provides an automatic and convenient testing method in the nondestructive testing of fiberboard defect and its density.

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