Application of Computed Tomography in Wood-polymer Composites density detection

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Abstract. CT technology was used in nondestructive testing procedure of Wood-plastic composite in the paper as well as computes the CT number range of different Wood-plastic composite tomography slices in statistic method. A fitting mathematical model between CT number and Wood-plastic composite density was Calculated, because of the linear relationship exists between Wood-plastic composite density and CT number. Hence, a new method in the nondestructive testing of Wood-plastic composite density was provided.

Introduction

Wood–plastics composites (WPC) are known as a new generation of materials for housewares, automotive and construction, etc. [1]. They combine the favorable performance and low cost attributes of both wood and plastics. In recent years, they have been developed rapidly, especially in North America.

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 [2]. 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 [3]. Obviously, CT is not only fit for the testing of logs, but is suitable for the testing of Wood-plastic composites as well. The research in this paper applied CT for Wood-plastic composite nondestructive testing.

Due to the linear relationship between density and CT number, the fitting linear formula was established by the mathematical model of CT number in each slice and comparison with real density of Wood-plastic composite. Thus, a new method for Wood-plastic composite density forecast is provided.

Structure of CT System and Imaging Principle

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. Attenuation diagram of Beer law is shown in Figure 1.

When ray imposes the object, ray intensity is:

When the object is heterogeneous:

$$I = I_0 e^{-\mu_1 d} \quad (1)$$

When the object is heterogeneous:

$$I = I_0 e^{-d\sum_{i=1}^{w}\mu_i} \quad (2)$$

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;

d is the length of each detected object.

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.

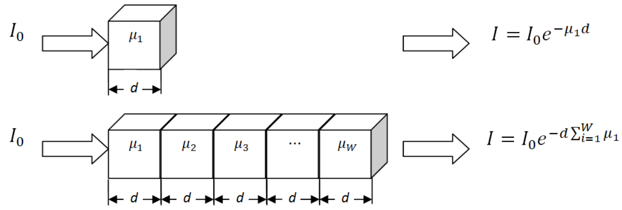

Fig. 1. Attenuation diagram of Beer law

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.

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.

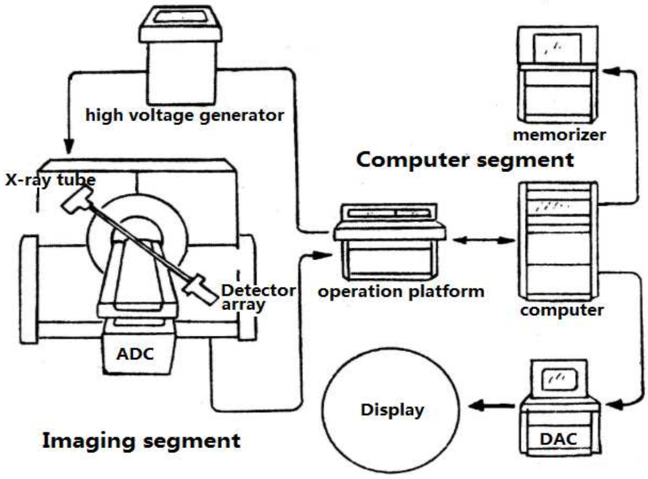

Fig. 2. Structure of CT scanning system.

Calculation of CT Number. 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 12 samples from different kinds of Wood-plastic composites were selected. 7 slices in each sample and 7 points in each slice were selected. That is, 49 points are selected in one sample. Table 1 shows the partial CT number of 12 samples.

Establishment Of Wood-Plastic Composite Density Formula

Because of the linear relationship between Wood-plastic composite density and CT number the linear fitting formula can be done by comparing with the mean of CT number in the slices with the Wood-plastic composite density. Table 3 expresses the Wood-plastic composite sample's mean of CT number and relative Wood-plastic composite density value.
The formula established from the data in Table 2 is:

Table 1. Partial CT Number (Hu) of 12 samples Slices

Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
183	196	437	653	315	395	391	91	16	-152	-54	101
112	153	407	441	354	350	407	-54	-229	-59	-28	99
59	139	467	481	337	494	452	-3	-99	-90	48	77
178	214	619	463	346	447	467	-66	-125	-51	78	75
…	…	…	…	…	…	…	…	…	…	…	…
214	180	455	567	277	534	543	84	-127	17	74	-4
120	200	345	556	328	534	475	72	-89	-41	71	-216
83	177	356	717	469	443	421	-74	-37	1	81	-146
140	215	456	535	346	409	427	-84	-170	40	84	43

$$y = 1.04202952 + 0.00082305 \cdot x \quad (4)$$

where x is the Wood-plastic composite CT number, y is the Wood-plastic composite density value. The relationship graph is shown in Fig. 3.

With the formula, the fast and automatic Wood-plastic composite density testing can be realized in the condition of Wood-plastic composite 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 Wood-plastic composite 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 Wood-plastic composite density testing.

Table 2. Wood-Plastic Composite CT Number And Relative Wood-Plastic Composite Density Value

Sample	Sample 1	Sample 2	Sample 3	Sample 4
CT number (Hu)	141	187	446	592
Density (g/cm3)	1.214	1.261	1.411	1.470
Sample	Sample 5	Sample 6	Sample 7	Sample 8
CT number (Hu)	359	480	500	-11
Density (g/cm3)	1.419	1.420	1.436	1．000
Sample	Sample 9	Sample 10	Sample 11	Sample 12
CT number (Hu)	-83	-30	61	50
Density (g/cm3)	0.957	0.977	1.078	1.076

Conclusion

After Comparing with conventional radiographic testing, Computed tomography (CT) testing method was selected for Wood-plastic composite nondestructive testing. 12 Wood-plastic composite samples were scanned by CT system. The CT numbers of each slice were acquired. The appropriate mathematical model between CT number and Wood-plastic composite density was found because of the linear relationship between Wood-plastic composite density and CT number. Using the model, the speed of Wood-plastic composite density testing was increased. Therefore an automatic and convenient testing method in the nondestructive testing of Wood-plastic composite density was provided.

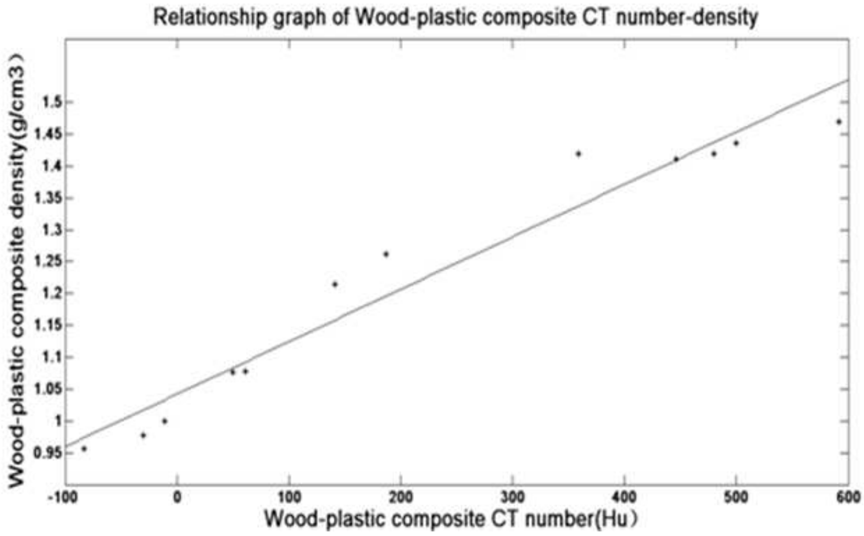

Fig. 3. Wood-plastic composite CT number-density relationship graph. R2 of fitting formula is = 0.951

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