the NDT Study of Metal Composite Material Tube

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Abstract

In view of the shedding problem of compound layer of composite material tubes in metallurgical industry, UT , ET and the special-purpose sensors are used to carry out the testing of the parent metal and the compound layer. According to practical testing, the conclusion can be obtained that this kind of integration method is advantageous for testing, which is provided with accurate results, clear signals and convenient operation etc..

Keywords: ultrasonic technology, eddy current testing, composite material tube, special-purpose sensors

1 . Summary

At present, interiorly, composite materials are mainly used in aviation and spaceflight, automobile industry, chemical industry, textile industry, machine manufacture and iatrology field. It is closely linked with people's lives. Therefore, testing of composite materials is very important. But if testing with a single testing method, the aim of testing the whole composite material (including surface and compound layer) cannot be achieved. Thus instruments integrated with multi-testing tools are needed to carry out testing.

2 . Composite material

Composite material is a kind of combination material which adopting one kind of material as matrix , and the other kind of material as reinforcement. Different materials can learn from other's advantageous performance and offset one's disadvantageous aspects, so cooperation effect can be achieved, which makes the synthetical performance of composite material better than the original materials. Thus composite material can meet all kinds of demands. Its matrix is divided into two kinds, including metal and non-metal. The often-used metal matrix includes aluminium, magnesium, copper, titanium or their alloy. Nonmetal matrix mainly includes synthetic resin, rubber, porcelain, graphite and carbon etc. The reinforcement material mainly includes fiberglass, fiber carbon, fiber boron, aramid fiber

reinforced plastic, fiber carborundum, fiber asbestus, crystal beard, tinsel and hard granule.

Composite materials are mainly applied in the following domains. Firstly, it's used in aviation and spaceflight field. On account of good heat stability and high specific strength and specific stiffness of composite material, it can be used to fabricate wings and front frames of airplanes, antenna support configuration, solar battery wing and crust, crust of huge carrier rocket, crust of engine and configuration component of space shuttles etc.. Secondly, it's used in automobile industry. Since composite materials is provided with special libration damp characteristic, it can decrease liberation and noise and has good anti- fatigue capability. It's easy to fix after damage and convenient for integral figuration. Thus it can be used in the fabrication of automobile bodywork, stressed components, transmission shaft, engine rack and its interior components. Thirdly, it's used in chemical industry, textile industry, machining manufacture fields. Materials compounded with fiber carbon and colophony are provided with good corrosion resisting property. So it can be used in fabrication of chemical industrial equipment, textile machines, paper machines, copycat, high speed machine tool and exactitude apparatus etc.. Fourthly, it's used in iatrology. Fiber carbon composite material is provided with excellent mechanics performance and special characteristic of non-absorbability of X ray, so it can be used to fabricate medical X-ray machine and reshaping rack etc.. Fiber carbon composite material also has biology structure compatibility and blood compatibility. It has good stability in biological circumstance. Thus it can be used as biological medical material. Furthermore, it can be used as physical sports fabrication material and architecture material.

3．Theory of Ultrasonic Testing

The principle of Ultrasonic Testing (UT) is shown in Figure 1. Ultrasonic transducer is adopted as transmitter which excitated stress wave inside the workpiece. And in the same surface, ultrasonic transducers are also set as receivers at every fixed distance. The testing purpose is evaluating the relative efficiency of stress wave propagation inside the workpiece. The basic property of testing is adapted to stress wave energy transformation, so it can better test the transmission and distributing of kinetic and stress energy. The work premise is that, in the course of loading, more effective stress energy and stress is indicating the increase of inner resistance. This hypothesis is based on the concept of interactional stress wave, which thought that spontaneous stress wave in the beginning of rupture will help craze rapidly unless their energy's expending on other mechanisms such as micro-crack plastic deformation. That is to say, the rapid effective consumption of stress wave energy removing from the crack concentration side needs the premise of energy not concentrating or pitching into disastrous rupture. The important meaning in the hypothesis is that the wave attenuation characteristic of material is very important. As for composite material, low attenuation is

usually referred to high intension and anti-attack ability.

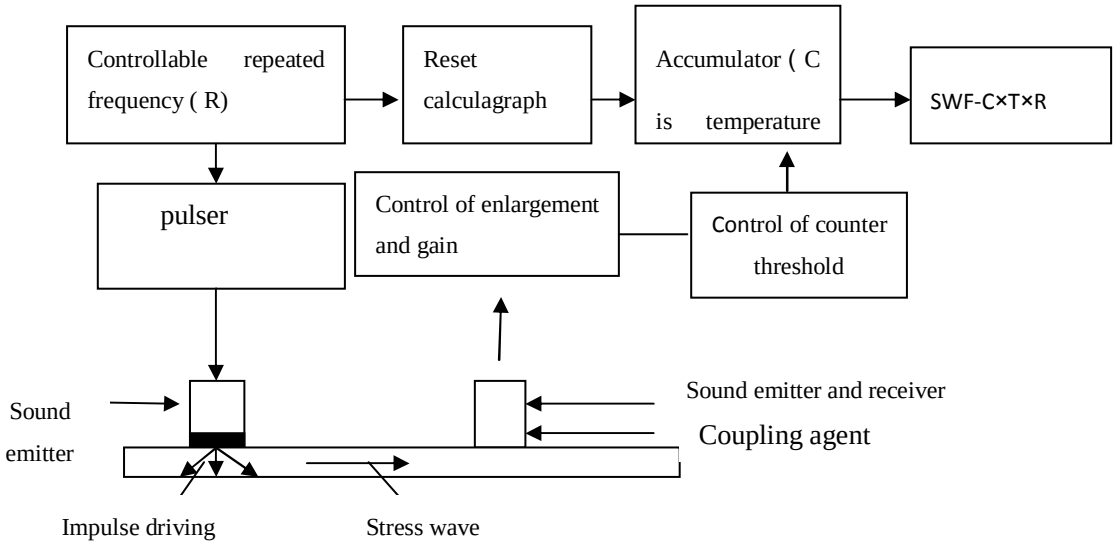

Figure 1 Principle chart of Ultrasonic Testing

UT is usually referred to the testing method which using a pair of ultrasonic piezoelectric transducers to send and receive the ultrasonic wave transmission in the component. A sending pulse transducer is chosen as the producing of wave, and the other receiving transducer is chosen to take the signals of the tested workpiece. Generally, the most convenient setting is that putting the two transducers into the same probe and making them parked in the same surface of tested workpiece, then carrying out testing at every fixed distance. In this paper, focusing longitudinal wave straight probe is used, of which work frequency is 10MHz. So the sending and receiving is located in the same probe. See Figure2.

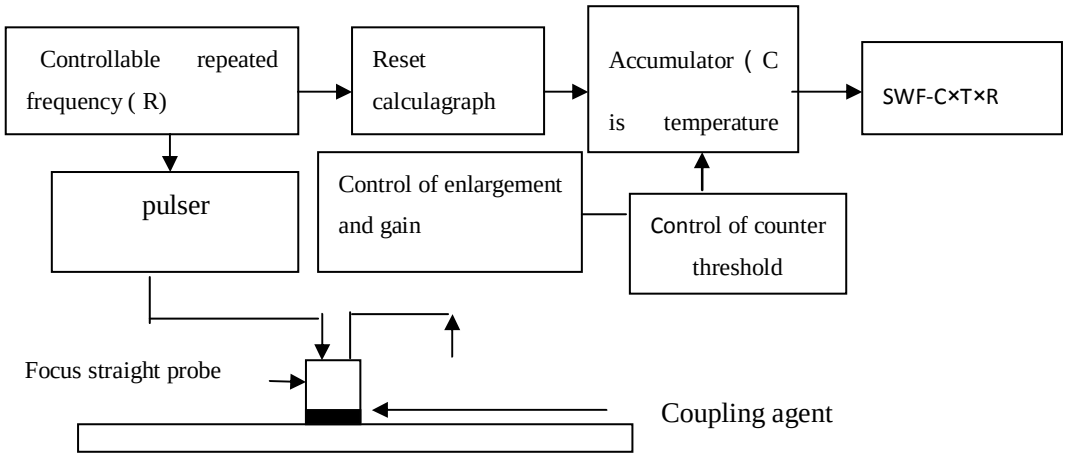

Figure 2 Principle chart adopting focus straight probe

The property of receiving signals ultrasonic testing is different from general supersound method. Supersound testing called as echo method is an incontinuous method which can reflect univocal waveform in the course of transmitting, while received signals of ultrasonic testing needs to be the result of interaction between a fixed volumn of sound wave and the material configuration and result of the multi-reflection, between the sending and receiving transducer.

4．Theory of Eddy Current Testing

Eddy Current Testing is a nondestructive testing method based on eletctromagnetic induction, which is adapted to electric materials. When electric conductor is in alternative magnetic field, there will exist induced current which is called as eddy current. As a result of various changes caused by conductor itself such as electric conductivity, magnetic permeability, shape, size and defects etc., this changing phenomenon can be used to judge the nature, state and defects of conductor. This kind of testing is called as eddy current testing(UT).

During eddy current testing, the conductor is put closed to alternating current loops. The effect of electric magnetic induction is caused between alternative magnetic field produced by loops and the conductor. Eddy current is coming into existence inside the conductor, which also affects the strength of the original magnetic field so as to cause the change of voltage and impedance of loops. When existing defects or any changes of nature in the surface or near-surface, the distribution of eddy current is changed, and accordingly the voltage and impedance is changed. Therefore, by testing the voltage or impendance change, the existence of defects or some other nature change can be detected.

Testing the discontinuity such as cracks and material loose on the surface and subsurface of parent materials with eddy current methods, eddy current probes can be chosen according to the diameter and standards for check and accept, such as through-type, spot-type single-channel, multi-channel etc.. And also some relative fittings can be chosen in view of some other testing demands, such as magnetic saturator etc..

5．Testing of Composite Material Tube

In view of the characteristic of composite material, eddy current and ultrasonic testing methods are integrated to carry out the detection.

a．The following items are what need our attention when testing by UT.

○,1 UT Coupling Agent

In order to improve the coupling effect, the medium exerting between the probe and the workpiece is called as coupling agent. Its main function is to remove the air between the

probe and the workpiece and make the ultrasonic transmit into the workpiece effectively so as to detect the defects. Besides, the coupling agent can be able to minish the friction. Commonly coupling agent should meet the demands as follows.

(1) Be able to the surface of workpiece and probe, with appropriate fluidity, viscosity and adhesive force, and easy to clean.

(2) High acoustic impedance, good sonolucency.

(3) Numerous and cheap source.

(4) No erosion to workpiece, harmless to human and no pollution to environment

(5) Stable performance, not easy to deteriorate and can be kept for long.

The commonly used coupling agents in UT include engine oil, transformer oil, glycerol, water and water glass etc.. In this paper, water is chosen as coupling agent.

○,2Choice of probe

Single straight probe or combined with double straight probe is utilized to carry out the longitudinal wave testing of composite materials. When testing, the first bottom wave in the fine part of composite material should be adjusted to 80% to 90% of the full range of the wave screen of instrument.

○,3 Judgement of defects

(1) Close acoustic impedances of two kind of materials

When the impedance of two kinds of materials of composite material is close, such as stainless steel and carbon steel composite material, in the good composite part, there is hardly interface wave. Testing from one side of the parent material, if no miss-meeting, there will not be defect wave, and only exist bottom wave. If there were incomplete miss-meetings, near the first bottom wave, there will exist waves in succession, and meanwhile the second bottom wave will decrease. If there were complete miss-meeting, the defect wave is much stronger and the first bottom wave will disappear. When testing from one side of the composite material, if no miss-meeting, there will be no defect wave but only bottom wave. If there were incomplete miss-meetings, the first bottom wave will decrease, and the defect waves will be in succession. If there were complete miss-meetings, the defect wave will be in succession and the width will increase, and the bottom wave will disappear.

(2) Greatly different acoustic impedances of two kinds of materials

Take the steelcopper composite material for example, the detailed operation procedures is as follows.

1、Prepare the composite material tube, testing instrument, sensor and auxiliary mechanic machines. Join them into a set of machine in the light of the guidelines of testing instrument.

2、Combine the sensor with the mechanics, and put together with the composite tube into the

water which is used as UT coupling agent.(See Figure 3).Now what needs attention is to keep the testing sensor perpendicular to the wall of the composite material tube so as to insure the consistent and veracity of testing.

Watch the echo wave in the screen of instrument, adjust the distance between sensor and tube wall. At this time, the first echo wave will exist peak value change, the first echo is required to be the reach the maximum.(See Figure 4). Now screw down the clamping screw, keep the distance between probe and the wall of composite material. By now, the debug course is over, and the normal testing can be carried out.

3、 Record the waveform gram of the whole testing course. Compared with the waveform gram of no-defect composite material tube, evaluate the waveform gram of defects. Save it for calling for experiment later.

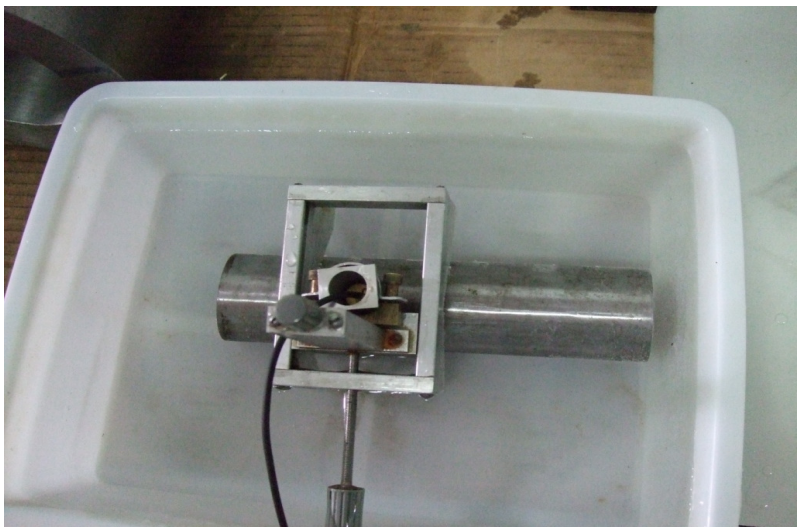

Figure 3 Sensor composite material tube and mechanism experimental apparatus

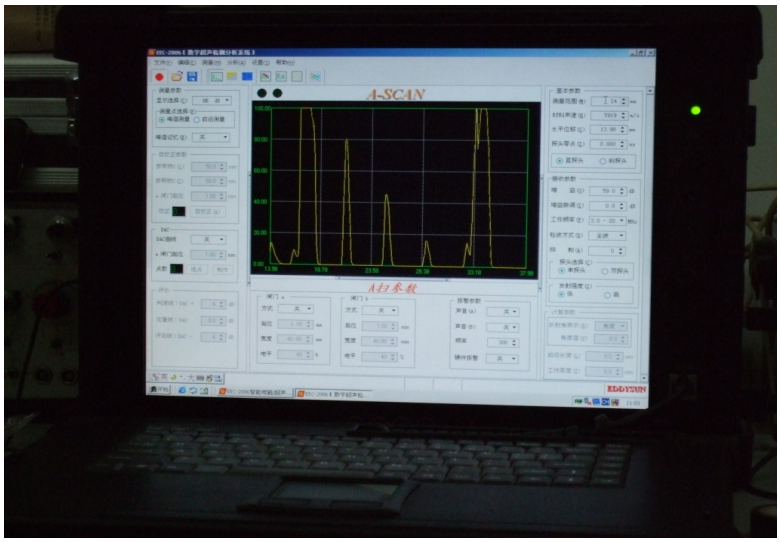

Figure 4 Real time testing waveform

The sample tube used is made of copper inside layer) and steel (outside layer) composite material. the man made defect is cut respectively into 2 loop grooves in the ends of the tube at 5cm point, simulating the lost phenomenon of inside copper layer.

During this experiment, the man-made defect in the sample tube of composite material is tested using UT, the testing waveform is as Figure 4. According to the distance of echo, the second summit point of wave is the echo of absciss layer between steel and copper material. If there is no defects in the tube (absciss layer or peeling off), the waveform should be the first, the third, the forth, the fifth echo as in the Figure 4.

b . When testing with ET, that can be divided into the following possibilities.

○,1 Using the out-through-type probe, it can only test the discontinuity of the surface of ferromagnetic materials. If using magnetic saturation which can make the ferromagnetic material partly, completely, equally magnetized, the testing sensitivity is greatly improved. For testing project which the accept standard is comparatively lower, this method can be used.

○,2 Using eddy current circumrotate testing. If the sensitivity of through-type probe cannot achieve the anticipative testing goal, this method can be used, which is distinctly more sensitive than the through-type method. There are two kinds of operation methods as follows.

(1)、The testing probe fixed, and the tested sample piece moving forward in helix. This method can greatly reduce the mechanic transmission cost in the product line. And it's easy to achieve, and redound to the protection of the probe. In this situation, the tested sample piece rotating, the partial magnetic saturation can be added into the system, and then smaller inner

defects can be tested.

(2)、The testing probe rotating, and the tested sample piece moving horizontally. Eight eddy current sensors can be arranged into array probe. When testing the probe is moving in helix relatively to the tube, every place of the composite material tube is assured to the tested. The design chart of probe is shown in Figure 5.

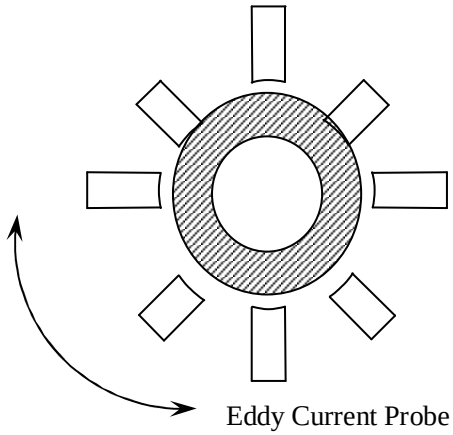

Figure5 Eddy current magnetic leakage probe array

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