NDE Characterization of Measurement Techniques in Composite Materials Using Terahertz Waves

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1. Introduction

The importance of terahertz waves (T-ray) for technical application is being recognized recently. Along with the advancement of T-ray technology and measuring instruments, the detection field using the electronic spectrum has emerged, and it is because it has a relatively shorter wavelength and a higher resolution than the microwave of T-ray. T-ray has a critical significance in the spectroscopic evaluation of security inspection system in airports and composite materials [1~4].

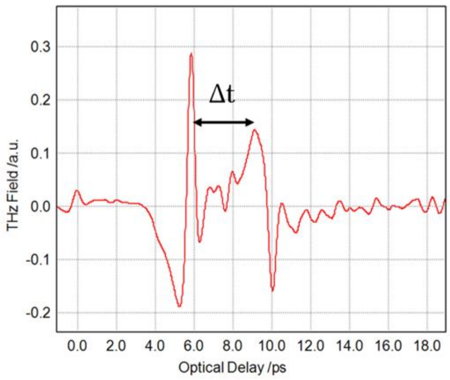
Also, the terahertz time domain spectroscopy (THz-TDS) plays a leading role in searching various defects or damages existing in composite materials accurately in the non-contact mode. This depends on creating necessary low-cycle Terahertz waveform through excitation of photoconductive antenna using femtosecond (10-15 second) laser.

Due to its excellent utilization in application technologies along with its wide-ranging applications, the THz-TDS has the potential to become the first small, mobile and reliable THz image device which is enough to be used practically. Therefore, this study was divided into two sections in the T-ray application. First, the Shim stock films are produced as a standard sample with thickness from tens of μm to hundreds of μm (see Figure 1). The thickness is measured and compared using the THz technology. Also, the other section is the study on the refractive index (n), absorption coefficient (α) and electrical conductivity of the Shim stock films for acquiring THz thickness measurement of Glass fiber reinforced plastics (GFRP).

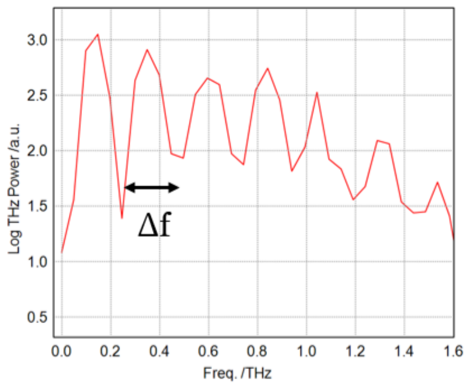
Fig. 1 Samples of Shim Stock films

2. Discussion and results

First of all, the measurement of amplitude of penetrating power was performed on various dependences of CFRP/GFRP composites according to the angle under 0.1 THz T-ray measured from 0º to 90º. Especially, CFRP composites showed almost a big change in the amplitude of penetrating power according to the angle. When measurement was carried out using the T-ray, CFRP composites were dependent on the direction indicating that it should be considered at the time of measurement. However the GFRP composites do not depend on the direction of fibers.



(a)A-scan image



(b)Frequency-domain signal

Fig. 2 A-scan image and frequency-domain signal in Shim stock films for T-ray reflection mode (thickness in Shim stock films is 0.381mm).

In order to measure the thickness of Shim stock films and GFRP composites using T-ray, the reflection mode which could measure it in the one direction was applied. At first, Figure 2 shows data of Shim stock films after T-ray scanning. The thickness of Shim stock films is 0.127 mm, 0.254 mm, 0.381 mm, 0.508 mm and 0.762 mm. This thickness values are used as the reference thickness of the film. Figure 2(a) shows the difference (Δt) in the time of flight (TOF) which indicates the difference be-tween the surface and back of Shim stock films. Figure 2(b) is the case that represents Figure 2(a) as FFT region, and Δf indicates the resonance frequency (Δt) which is correlated with the thickness of Shim stock films. At this time, Δt which is the difference in TOF is the reciprocal of Δf. In other words, 1/Δt is Δf. The thickness of Shim stock film is 0.381 mm at this time.

Shim stock films with non-conductivity and GFRP composites were not dependent on the direction of T-ray, so the measurement was possible using T-ray. Also, the reflection mode which could enable measurement in one direction was applied. At first, Figure 3 shows the comparison between the nominal thickness of Shim stock films and the thickness measured using T-ray. This line shows proportional relation with the standard thickness. Here, □ is the case of measurement by assuming T-ray is vertical to the specimen, and △ is the case of inclined T-ray. Figure 4 shows the comparison between the nominal thickness of GFRP composites and the thickness measured using T-ray. The thickness of GFRP composites is 2.02 mm, 3.08 mm, 5.74 mm and 5.92 mm. Just as in Figure 6, □ is the case of measurement by assuming T-ray is vertical to the specimen, and △ is the case of inclined T-ray. Unlike the thickness in μm size, the case of inclined T-ray matched with the standard thickness in case of thickness in mm size. The penetration ratio of T-ray is very high, enabling to optimize a reception signal, so its applicability is very high.

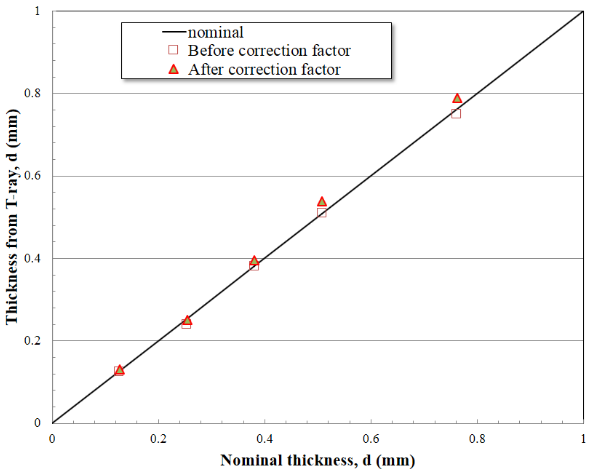


Fig. 3 Relation between nominal thickness and thickness measured from T-ray techniques in Shim stock films.

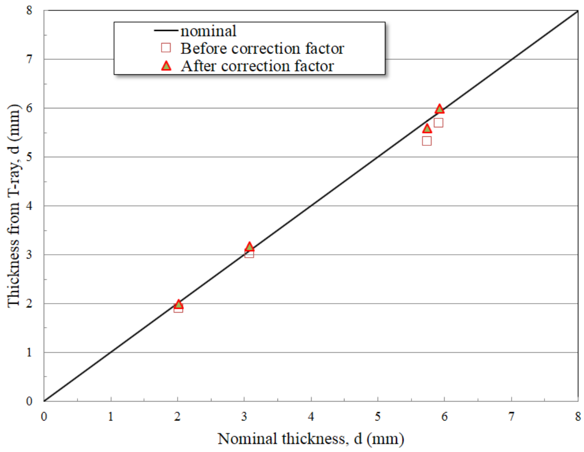


Fig. 4 Relation between nominal thickness and thickness measured from T-ray techniques in GFRP composites

3. Conclusions

In this study with regard to the application and utilization of T-ray on non-destructive examination of Shim stock films and GFRP composites, the measurement technique of refractive index of T-ray which was one of material properties was established. Also, the limitation in the energy penetrating power of T-ray according to the conduction characteristics of GFRP composites and the fiber lamination angle of CFRP was reviewed, and it was possible to obtain the THz technique which could measure the thickness of Shim stock films in μm size and GFRP composites.

Acknowledgment

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