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Ultrasonic Properties of a Rubber Toughened Structural Adhesive
ゴム粒子によって強化された構造用接着剤の超音波物性

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1. Introduction

The 'structural adhesive' is defined generally as one having high reliability and holding low degradation of adhesion properties such as adhesive strength and environmental resistance under a large load for a long time. Structural adhesive is used widely for such manufacturing industry as aviation, automotive, building construction. The composition of many commercial adhesives is homogeneous, but that of structural adhesive is the composite of e.g. resin and rubber particles in order to provide excellent adhesive characteristics to adhesiveness.[1)] Rubber particles in resin can improve the shock resistence and brittleness of adhesives. In the field of ultrasonics, though there are many researches related to homogeneous adhesive, such composite adhesive as resin and rubber has been studied rarely. One reason for this is that ultrasonic wave attenuates largely when propagating in the adhesive layer as shown in this study.

A structural adhesive composed of Poly-methyl-methacrylate (PMMA) resin and dispersed rubber particles is investigated by pulse-echo method. In our previous study, the sound velocities and the elastic constants of a adhesive layer were evaluated.[2)] We now determine the frequency dependency of the attenuation constants using spectrum analysis, and velocities and the results are compared with that of genuine PMMA.

2. Experimental Method

We used the same structural adhesive and ultrasonic pulse measurement system as described in the previous work.[2)] The thickness of the specimen that was adhered on an aluminum plate was 0.520 mm. A plate (thickness 4mm) of acrylic resin was measured by the same system for a comparison. The microstructure of adhesive was observed by scanning electron microscope (SEM) using the staining technique and the rubber contained in adhesive was identified by pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS).

The frequency dependency of attenuation constant α was determined by the formula[3)]

$$\alpha(f) = \frac{1}{2d}\left(\ln\frac{1-R^2}{R} + \ln\frac{|F_r|}{|F_1|}\right)$$

where

$$R = \sqrt{\frac{|F_r||F_2|}{|F_r||F_2| + |F_1|^2}}$$

and d, $|F_r|$, $|F_1|$ and $|F_2|$ are the thickness of adhesive layer, the spectrum of a reflection echo, first echo and second botom echo, respectively. Phase delay $\Delta\tau(f)$ was calculated by integrating group delay[3)] and phase velocity was obtained from $2d / \Delta\tau(f)$.

3. Results and Discussion

Figure 1 shows the microstructure of adhesive, where brighter regions in the figure indicate rubber particles. Two types of the rubber particles varying in size are distinguished and occupy about the half of the area. Therefore, it is said that about the half of the adhesive will consist of rubber.

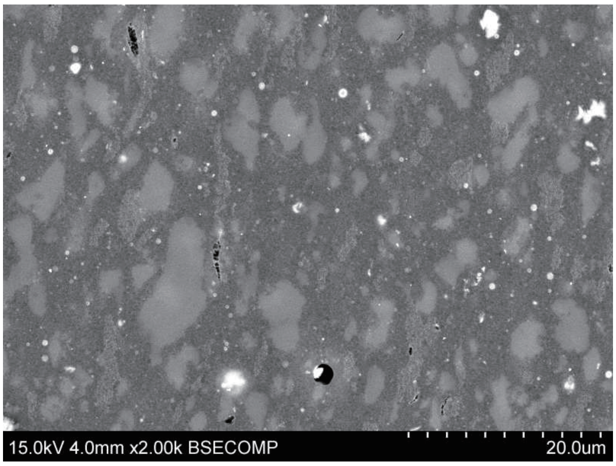
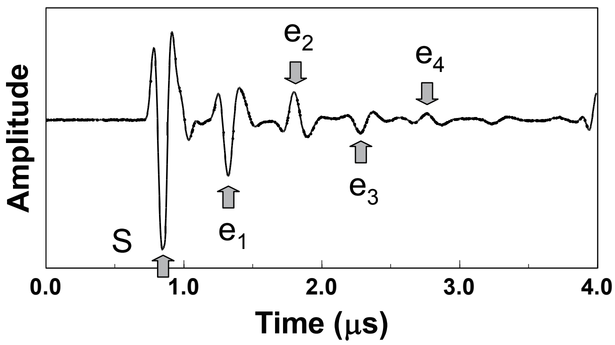


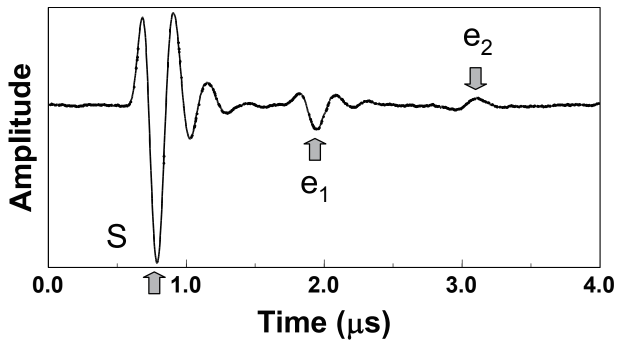
Fig. 1 Microstructure of adhesive (brighter regions indicate rubber)

The result of Py-GC/MS analysis suggested that the main component of rubber contained in the adhesive was styrene-butadiene type.

Longitudinal and transverse wave forms observed in the measurement and their spectrum



(a) Longitudinal wave



(b) Transverse wave

Fig. 2 Ultrasonic echoes obtained in experiment ("S" indicates reflection echo of the interface between adhesive and aluminum plate and "e" does bottom echo of adhesive.)

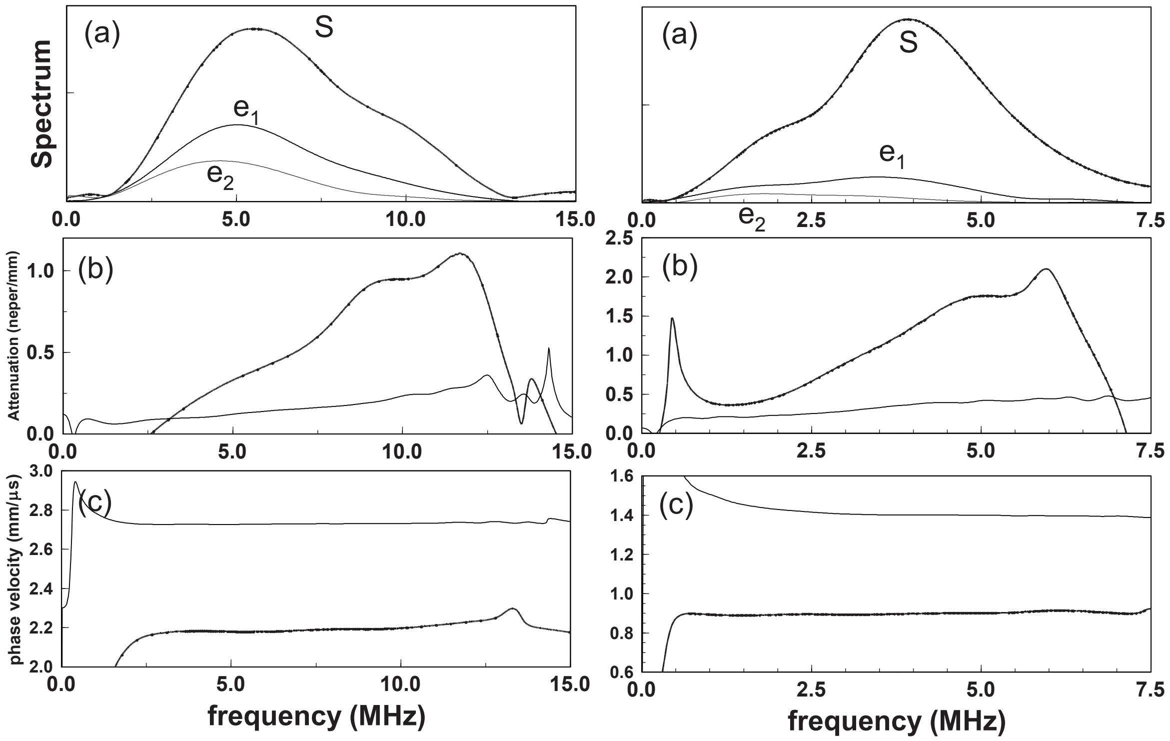


Fig. 3 Spectrum analysis of longitudinal waveform (left) and transverse waveform (right) overplotted that of acrylic resin by a dotted line.
(a) , (b) and (c) are spectrum, attenuation constant and phase velocity, respectively.

analysis are shown in **Fig. 2** and **Fig. 3**, respectively. In the figure, the result of the analysis of acrylic resin is also added by a dotted line.

The attenuations of transverse wave of both adhesive and acrylic resin are greater than that of longitudinal one. As frequency increases, the wave attenuations in adhesive increase remarkably, compared with acrylic resin. This will be understood from the existence of rubber particles, which disperse waves strongly as the frequency of wave increases. The wave velocities of adhesive are smaller than those of acrylic resin and the transverse wave. The ratio of decrease of the transverse one is larger than the longitudinal one.

4. Summary

Structural adhesive toughened by rubber was investigated by using spectrum analysis. The results suggested the great influence of rubber particles.

References

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