Non-contact measurement of firmness properties using T-DPLUS

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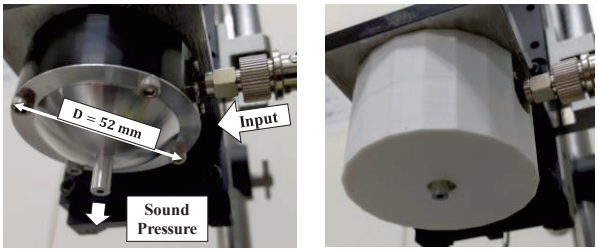
1. Introduction

T-DPLUS (Tube-Type DPLUS)[1)] is an improved version of DPLUS (Double Parabolic refLectors wave-guided Ultrasonic tranSducers)[2)]. Fig. 1 shows T-DPLUS with and without a cover. There is a hole that allows light to pass through. Input power is produced from the connector on the side, ultrasonic wave is emitted from the tip.

In this study, we measured characteristics of T-DPLUS in the air, comparing it with and without the cover. The cover was made of PLA, and covers the first reflector of T-DPLUS. In addition, how different elastic phantoms vibrate by T-DPLUS using LDV (Laser Doppler Velocimeter) to examine whether it can be used for non-contact firmness measurements conducted in Tabaru lab[3, 4)].



(a) (b)

Fig. 1 Picture of (a) uncovered and (b) covered T-DPLUS.

2. Experimental method

2.1 Measurement of acoustic pressure characteristics of T-DPLUS

Fig. 2 shows the setup to measure the acoustic characteristics of T-DPLUS in the air. XY-stage, function generator and oscilloscope were connected to PC via GPIB connection, and they were controlled by Python. In this report, basically, the input voltage of T-DPLUS was 20 V_{pp}. The driving frequency of the input burst wave was 117 kHz. The length between T-DPLUS and a 1/6" condenser microphone (7116, 4116, ACO) was 3.2 mm. The 99th percentile of the absolute value of the outputs

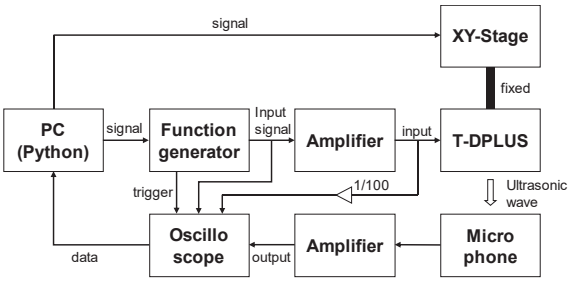


Fig. 2 Measurement system of acoustic pressure characteristics of T-DPLUS.

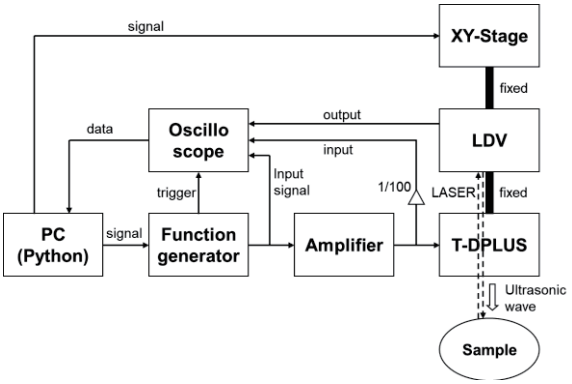


Fig. 3 Firmness measurement system.

was used as the score of each measurement of T-DPLUS characteristics.

2.2 Vibration measurement of elastic phantoms

Fig. 3 shows the setup to measure firmness properties of phantoms. The laser of LDV reaches to the phantoms through the hole of T-DPLUS. The length between the tip and the surface of phantoms was 3.2 mm. Input voltage was 100 V_{pp}. The frequency was 117 kHz. The bursted waves (5 waves) was used. Elastic phantoms (50 mm^3, OST) with different Young's moduli (30, 75, 200, 400 kPa) were used as specimen.

3. Results and discussion

Sound pressure distributions of covered and uncovered T-DPLUS are shown in Fig. 4. The maximum sound pressure of the covered was 74.0 Pa. The uncovered one was 46.9 Pa. The half width of the covered was 3.9 mm. The uncovered one had 5.7 mm. Obviously, the covered version has better

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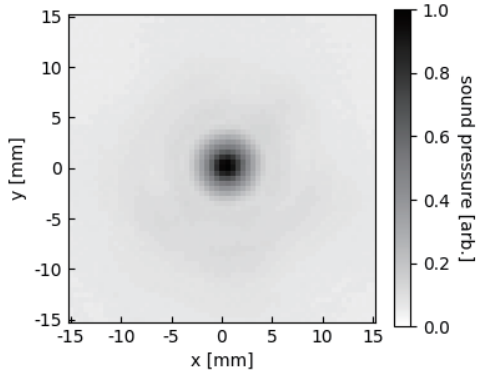
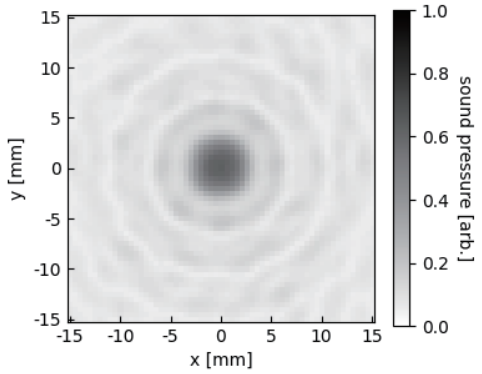
characteristics: sharp pointed tip and high intensity. There might be unexpected noisy waves produced from the structure of T-DPLUS, because there are interference fringes in Fig. 4(b). The cover was effective to prevent the noisy wave from spreading and interfering with the expected wave produced from its tip.

Distance characteristics of T-DPLUS is shown in Fig. 5. The "*z*" is the length between the tip of T-DPLUS and the microphone. The peaks matched. The maximum sound pressure was 111.9 Pa at approximately 1.8 mm of the covered. The covered version's intensity was bigger than the uncovered in the near field. However, beyond 5 mm, the former was smaller than the latter.



(a) covered



(b) uncovered

Fig. 4 Sound pressure distribution of covered and uncovered T-DPLUS.

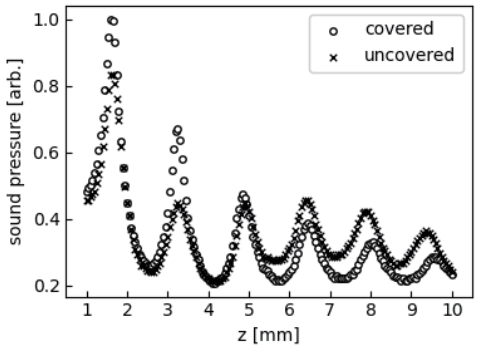


Fig. 5 Distance characteristics of covered and uncovered T-DPLUS.

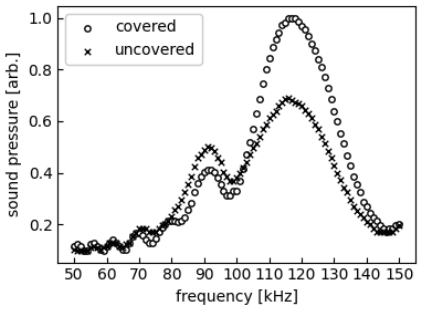


Fig. 6 Frequency characteristics of covered and uncovered T-DPLUS.

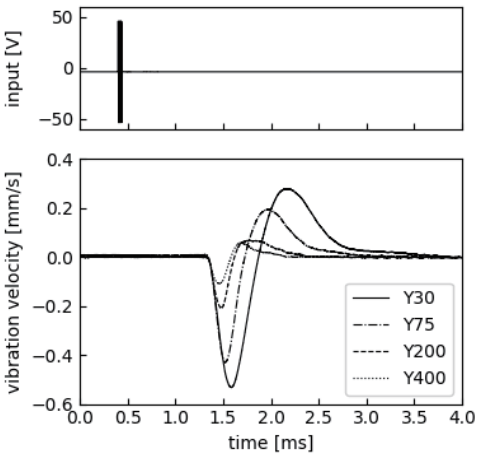


Fig. 7 Vibration characteristics of elastic phantoms.

Frequency characteristics of T-DPLUS is shown in Fig. 6. The best frequency to use was 117 kHz. At approximately 90 kHz, the uncovered has larger sound pressure.

Fig. 7 shows how the different elastic phantoms vibrate by T-DPLUS. The softer the phantom, the greater the amplitude and wavelength.

4. Conclusion

T-DPLUS can be used for non-contact firmness measurement in the air. It should be covered to prevent the unexpected noises from interfering and weakening the wave produced from the tip.

References

1) K. Yamada, K. Chen, T. Irie, T. Iijima and T. Morita, Acoust. Sci. & Tech. **43**, 287 (2022).
2) K. Chen, T. Irie, T. Iijima and T. Morita, IEEE Trans. Ultrason. Ferroelectr. Freq. Control **67**, 1620 (2020).
3) M. Tabaru and K. Nakamura, Proc. 2015 Spring Meet. Acoustical Society of Japan, (2015) p.1121 [in Japanese].
4) C. Wu and M. Tabaru, IEICE Tech. Rep. US2016-123 (2017).