1P4-7

Non-contact imaging of foreign substance inside soft material using high-intensity aerial ultrasonic waves
強力空中超音波を用いたソフトマテリアル内部異物の非接触イメージング

Li Jin†, Ayumu Osumi, and Youichi Ito (Coll. Sci. and Tech., Nihon Univ.)
金麗†，大隅歩，伊藤洋一（日大理工）

1. Introduction

We have studied a method for detecting a foreign substance inside a soft material by using high-intensity aerial ultrasonic waves[1]. In this study, we propose a hybrid imaging method that uses simultaneously the characteristics of the vibration velocity and static displacement that are generated on the object surface by irradiation of high-intensity sound waves, taking advantage of the merits of both. In this paper, we introduce this basic investigation.

2. Experimental apparatus and measurement method

Fig. 1 shows an overview of the experimental apparatus that was constructed to realize the proposed measurement method. These devices comprise a source of high-intensity aerial ultrasonic waves, a laser Doppler vibrometer (LDV), a data logger, and a PC that controls the other equipment. To generate high-intensity aerial ultrasonic waves, we use a point-converging sound source[2] with a stripe-mode vibration plate (driving frequency: 28 kHz). The sound source, whose circular focal area is approximately 130 mm from the opening of the sound source and has a diameter of approximately 15 mm, generates a sound pressure of approximately 4 kPa at a supply power of 10 W. Moreover, an acoustic window (diameter: 20 mm; thickness: 2 mm) is placed at the focal point of the sound waves to decrease the effect of the side lobes on the imaging results.

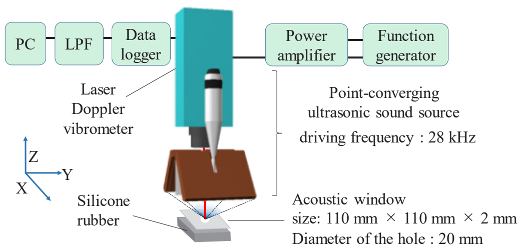


Fig. 1 Experimental apparatus

The experiment is conducted according to the following procedure. First, focused sound waves are irradiated on the sample for 1 s and then irradiation is stopped for 1 s. The vibration that is generated on the object surface during this 2 s period is measured by the LDV, which is placed behind the sound source. Then, only the vibration velocity information is extracted by a band-pass filter (center frequency: 28 kHz) from the output signals of the LDV. In addition, the waveform of the velocity variation of the surface displacement is obtained by a 10-Hz low-pass filter, and the static displacement is calculated by integrating the signal. With this series of operations done on the measurement area of the object surface, the vibration velocity and static displacement are measured simultaneously, and imaging of foreign substance can be obtained from their amplitude distributions.

Fig. 2 shows an overview of the sample that is used in the experiment. The normal portion of the sample, which is relatively soft, is made of 50% silicone and 50% diluent. The foreign-substance portion, which is a little harder than the normal portion and is made of 100% silicone without diluent, is inserted at the center of the sample as shown in **Fig. 2**. In the experiment, regarding the sample (foreign substance: diameter 20 mm; depth from surface 3 mm), the measurement area is 61 mm × 61 mm centered on the portion in which the foreign substance is inserted. The measurement is conducted with steps of 2 mm (total: 961 points) at a supply power of 10 W to the sound source (overall pressure: 4 kPa).

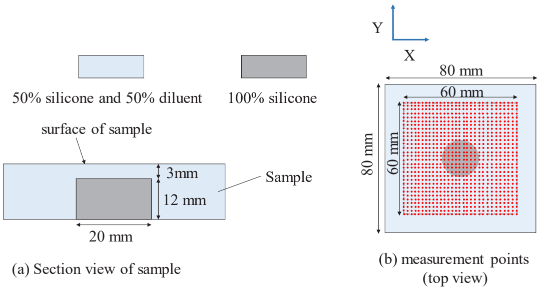


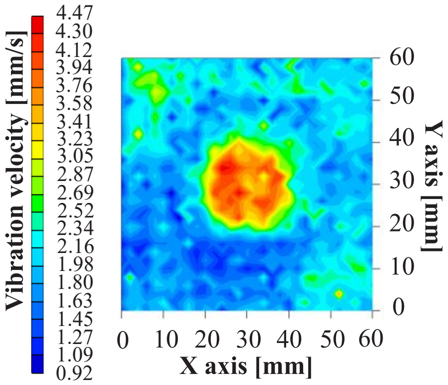
Fig. 2 Overview of sample

3. Measurement results

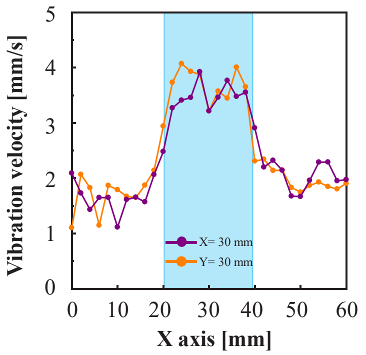
Fig. 3(a) and **(b)** show the measurement

osumi.ayumu@nihon-u.ac.jp

results for the vibration velocity distribution. **Fig. 3(a)** shows a color map of the vibration velocity distribution over the whole measurement area. The amplitudes in the foreign-substance portion exceed those in the other portion, allowing the foreign substance to be detected. This is because the surface hardness of the portion in which the foreign substance is inserted increases apparently. **Fig. 3(b)** shows the vibration velocity distributions along the lines x = 30 mm and y = 30 mm in **Fig. 3(a)**. The amplitude ratio of the foreign-substance portion to the normal portion is approximately two.



(a) In-plane distribution

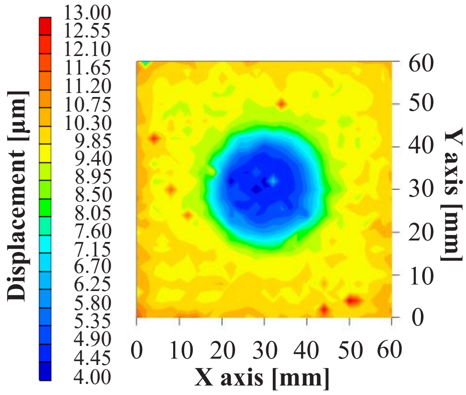


(b) Line distribution

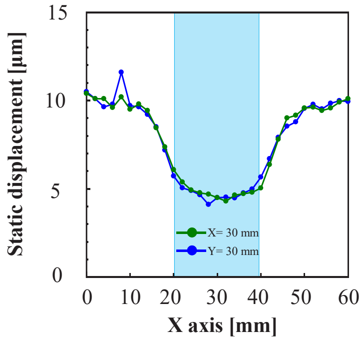
Fig. 3 Results of vibration velocity

Fig. 4(a) and **(b)** show the results for the static displacement distribution. **Fig. 4(a)** shows a color map of the static displacement distribution over the whole measurement area. The static displacement in the foreign-substance portion is less than that in the normal portion, allowing the foreign substance to be detected. **Fig. 4(b)** shows the static displacement distributions along the lines x = 30 mm and y = 30 mm in **Fig. 4(a)**. The values in the foreign-substance portion are approximately half those in the normal portion. Here, comparing the vibration velocity and static displacement, the static displacement is better for imaging the shape of the foreign substance, and the variations in its measurement values are less. However, the imaged foreign substance is a little larger than the real one.

From the above, regarding imaging by the proposed method, which uses the characteristics of



(a) In-plane distribution



(b) Line distribution

Fig. 4 Results of static displacement

both the vibration velocity and static displacement, the imaging results of both contain some useful features. By taking advantage of these features, better detection and imaging of foreign objects are possible.

4. Conclusions

We propose a hybrid imaging method that uses the characteristics of the vibration velocity and static displacement that are generated simultaneously on the object surface by irradiation of high-intensity sound waves, taking advantage of the merits of both. Furthermore, we attempted to use this method to image a hard foreign substance inside a soft material (silicone gum) in a non-contact way. From the results, the distributions of vibration velocity and static displacement obtained by irradiation of sound waves on the object surface showed opposite characteristics in the normal portion and the foreign-substance portion. In addition, given the different features of the two characteristics, it is possible to use both to improve the detection and imaging of foreign substances.

References

1. L. Jin, A. Osumi, and Y. Ito: Spring Meeting Acoustical Society of Japan (2018) p. 995-996.
2. Y. Ito: Jpn. J. Appl. Phys. **48** (2009) 07GM11.