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Downsizing of Impact-reduction Device Using Ultrasonic Transducer
超音波振動子を用いた衝撃軽減装置の小型化

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1. Introduction

We aim to develop an impact-reduction system by applying the ultrasonic vibrations that can change the rigidity of the material instantaneously in the event of an impact. Various studies have focused on the use of ultrasonic vibrations for plastic deformation [1, 2]. We have previously reported on the deformation and impact-reduction characteristics when applying ultrasonic vibrations to several materials [3, 4]. The length of the ultrasonic transducer was 435 mm. In order to apply the impact-reduction system to a crushable zone in vehicles, the size of the transducer is overlarge. Overlarge transducer reduces fuel economy. Furthermore, it is difficult to drive many transducers. Therefore, downsizing of impact-reduction device is important. The purpose of this study is to confirm the impact-reduction effect of the ultrasonic vibrations using a downsized ultrasonic transducer. The vibration characteristics of the ultrasonic transducer, the deformation characteristics, and the impact-reduction characteristics were measured.

2. Configuration

Fig. 1 shows the configuration of the experimental equipment that consists mainly of a bolt-clamped Langevin-type transducer (BLT) with a stepped horn, a drop weight (4.4 kg) for impact testing, a jig, and a dynamic force sensor. These components except for the sensor can be separately moved up and down by attaching them to a slide guide. **Table. I** shows the specifications of the experimental equipment. The transducer length, BLT diameter, and weight were reduced to 45%, 74%, and 20%, respectively.

The stepped horn is installed to increase the vibration amplitude. The material of the horn is titanium alloy (ASTM B348 Gr5). The crumple plate specimens are 200, 10, and 2.3 mm in length, width, and thickness, respectively. The material of the crumple plate is high-tensile steel (WEL-TEN590RE). The ultrasonic transducer is pressed against the crumple specimen at the edge of the horn.

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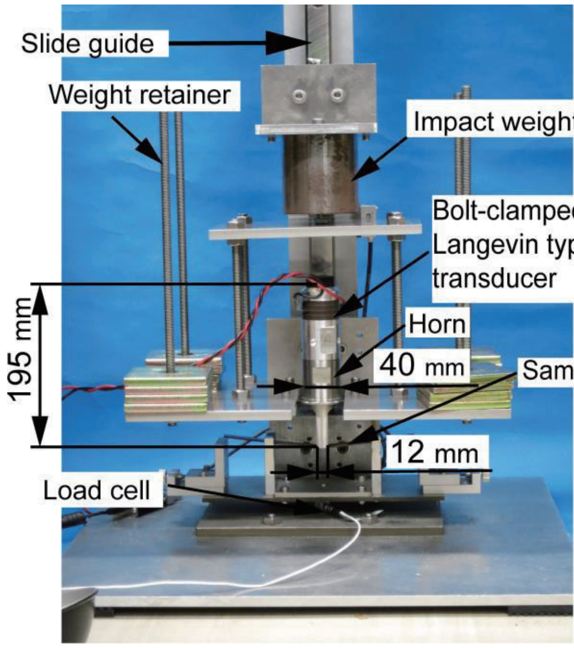

Fig. 1 Configuration of experimental equipment for impact-absorbing test by applying ultrasonic vibration.

Table. I Specifications of experimental equipment.

	Transducer length (mm)	BLT diameter (mm)	Resonant frequency (kHz)	Weight (kg)
Early study	435	54	17.2	4.54
This study	195	40	25.3	0.92

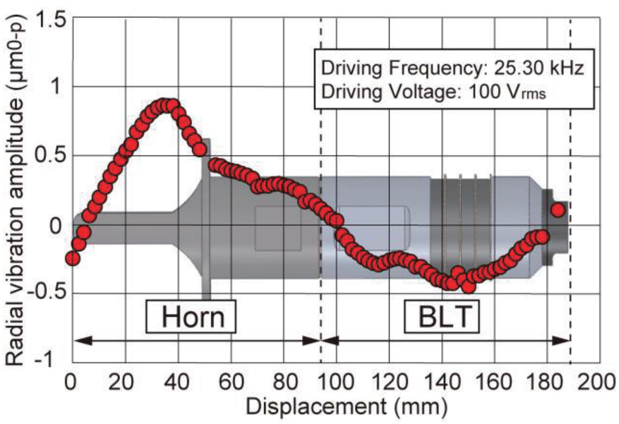

Fig. 2 Radial vibration amplitude distribution along ultrasonic transducer under no-load condition.

3. Vibration characteristics

Fig. 2 shows the radial vibration distributions along the transducer. It is confirmed that the vibration amplitude is expanded by the horn. The nodes of the radial vibration distributions exist at both ends of the horn; this indicates that the ultrasonic transducer is driven almost as designed.

Fig. 3 shows the admittance loops of the only BLT and the BLT with the horn. The resonant frequency was changed from 27.28 kHz to 25.30 kHz by connecting the horn. Furthermore, the motional admittance was decreased. It would appear that the length of the horn is not appropriate.

4. Deformation Characteristics

The relationship between the static load and the deformation amount in the vertical direction was measured as shown in **Fig. 4**. The deformation amount shows a sharp rise at approximately 320 N when the ultrasonic vibrations were not applied. On the other hand, the deformation amount shows a sharp rise at approximately 280 N when the ultrasonic vibrations were applied.

5. Impact-reduction characteristics

Fig. 5 shows the impact waveforms when the ultrasonic vibrations were applied and when they were not applied. The fall height of the impact weight was 150 mm. The peak value of the impact force was reduced by the application of the ultrasonic vibrations from 275 N to 226 N (17.8% reduction).

6. Conclusion

We developed the downsized-impact-reduction device using the ultrasonic transducer. In this study, we measured the vibration characteristics, the deformation characteristics, and the impact-reduction characteristics. The following main results were derived from this study:

(1) The resonant frequency was changed by connecting the horn. Furthermore, the motional admittance was decreased. The effect of ultrasonic vibrations may be further enhanced by improving the design of the horn.

(2) The impact force was reduced by 17.8% by the application of ultrasonic vibrations.

Acknowledgment
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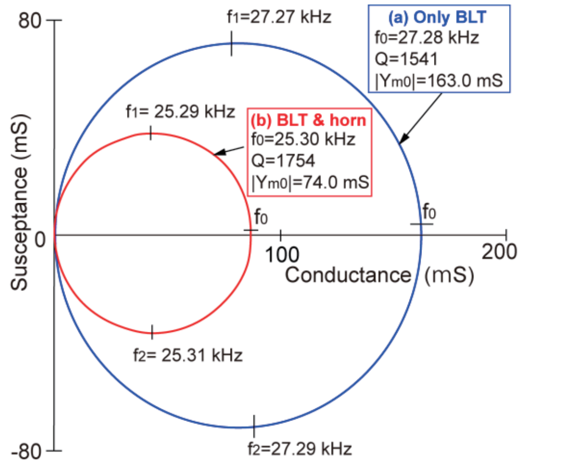

Fig. 3 Admittance loops of (a) only BLT and (b) BLT with horn.

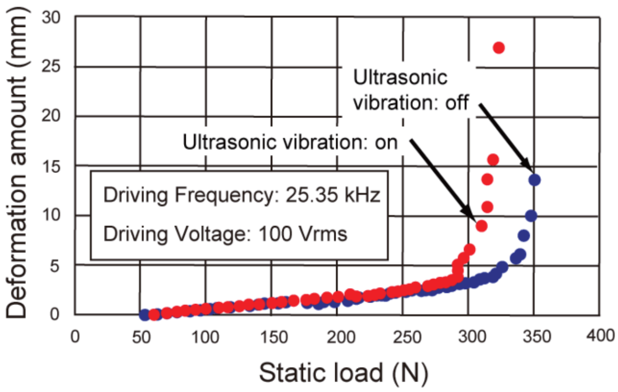

Fig. 4 Relationships between static load and deformation amount.

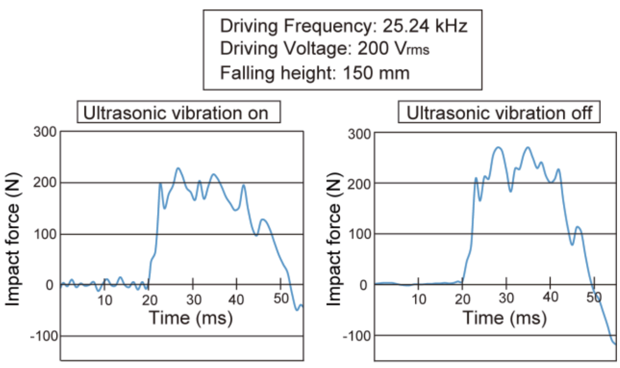

Fig. 5 Impact waveforms when ultrasonic vibrations were applied and when they were not applied.