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Design of polymer wedge for exciting high intensity surface acoustic waves on glass plate

高強度弾性表面波をガラス面に励振するための樹脂くさびの設計

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1. Introduction

Advanced Driver Assistance System (ADAS) is attracting attention as a means of improving automobile safety. ADAS is supported by various kinds of sensor technologies, including cameras to recognize the surrounding environment. Raindrops and other factors may reduce the recognition quality in practical use. A mechanical wiper is the main device to remove raindrops from windshields, but the wipers do not reach the view of the front camera in many practical designs, and the wiper itself blocks the camera view. Recently, in addition to the front view camera, other places such as back and side views require cameras. There are trials to replace door mirrors with cameras to improve the aerodynamic design. This increase in the number of cameras will result in an increase in water tanks, and it will cause excess weight.

To overcome this difficulty, we have been investigating the removal of raindrops with surface acoustic wave (SAW) using a wedge transducer[1]. The front shield usually has a triple-layered structure, where two glass plates sandwich a thin rubber layer. The frequency of SAW was discussed to confine the wave energy in the top layer and determined at around 2 MHz. Polyphenylene sulfide (PPS) resin was chosen for the wedge body since the ultrasonic attenuation under high vibration amplitude is lower than other engineering plastics[2]. The wedge angle was determined according to the deflection law and simple numerical simulations. An efficient operation method was investigated to reduce the input electrical power to remove droplets on the glass[3]. However, the design of the wedge was not necessarily optimized. In this report, using finite element simulation, the wedge shape is investigated to maximize the transformation efficiency from the thickness vibration of the piezoelectric element to the vertical vibration on the surface of the glass.

2. Configuration of the wedge transducer

Configuration of the wedge transducer is illustrated in **Fig. 1**, and the cross-section photo is pasted in **Fig. 2**. A rectangular PZT plate of thickness mode is bonded on the angled surface of the wedge transducer. The thickness of the PZT plate is tuned to resonate at 2 MHz. This frequency was so determined that the SAW wavelength on the glass plate should be less than the thickness of the glass plate. According to the previous study[1], the optimum angle for the PPS wedge and the glass plate is 45 degrees.

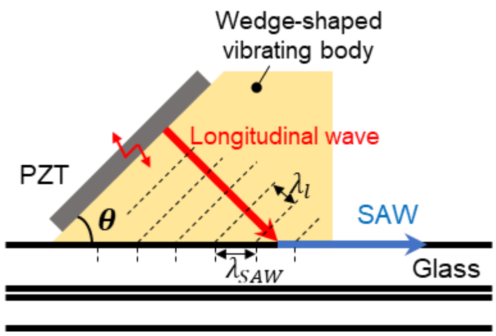


Fig. 1 Wedge transducer bonded on triple-layered glass plate.

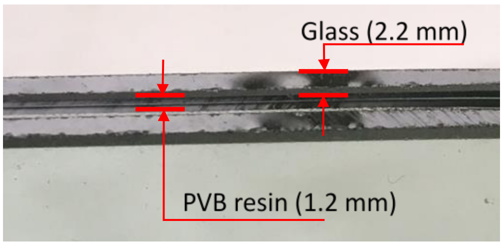


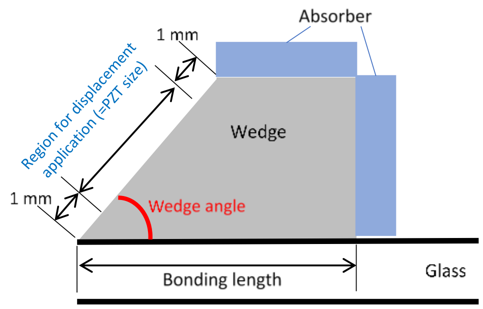
Fig. 2 Cross section of typical front shield glass.

3. Wedge shape design

3.1 Simulation model

The model for finite element analysis is illustrated in **Fig. 3**. A vibration displacement at 2 MHz is applied uniformly within the region on the slope surface, where a rectangular PZT plate is bonded in the real wedge transducer. Wedge is made of PPS. The other two surfaces are attached with absorbing elements to avoid unwanted reflections. The material parameters are listed in **Table 1**. This is a two-dimensional harmonic analysis conducted on ANSYS 2019 R3. A typical example of the simulated results is shown in **Fig. 4,** where the color indicates the sum of displacement.

We chose the wedge angle and bonding length as design variables. The bonding length is the bottom length of the wedge which is perfectly bonded on the



glass surface.

Fig. 3 Model for simulation.

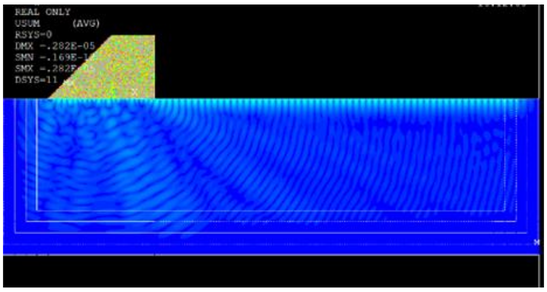


Fig. 4. An example of simulated results.

Table 1 Parameters used in the simulation.

	PPS	Glass
Young's modulus [GPa]	3.95	73.5
Poisson's ratio	0.40	0.17
Density [kg/m^3]	1357	2200

3.2 Wedge angle

Although the ideal wedge angle is calculated to be 45°, we need to know the range of angle error acceptable for practical operation. For example, the sound speed of the wedge varies due to the change in the density caused by the temperature drift. PPS is a polymer material, and its material parameters vary depending on the production process. We calculated the ratio of the vertical displacement on the glass to the displacement given on the slope of the wedge as functions of the wedge angle. The measured sound speed is 2496 m/s. The sound speeds for the temperature change of ±100℃ from the reference (23℃) are 2478 and 2514 m/s, respectively, if we consider the thermal expansion. In **Fig. 5**, calculated results for 2420, 2496, and 2550 are plotted, which may include enough range of thermal expansion experienced in normal use. We can conclude from the results that the wedge angle of 45° is appropriate even if the 100℃ temperature drift or 2-3° of machining error in the wedge angle occurs.

3.3 Bonding length

Next, we examined the effect of the bonding length. In this simulation, the PZT width and the wedge angle were fixed at 10 mm and 45°, respectively. The results are summarized in **Fig. 6**. The geometrical projection of the PZT element on the boundary between the wedge and glass is 15.6 mm. The results imply that the bonding length should be shorter than the projected length by approximately 10%.

4. Summary

The shape of the wedge was optimized in the simulation to increase vibration velocity. The wedge angle of 45°, the bonding length of 12-13 mm, and the PZT size of 8-12mm were found to be optimal. We will confirm these results through experiments in the near future.

Acknowledgment

Machining of polymer wedge was conducted at Design and Manufacturing Division, Open Facility Center, Tokyo Institute of Technology.

References

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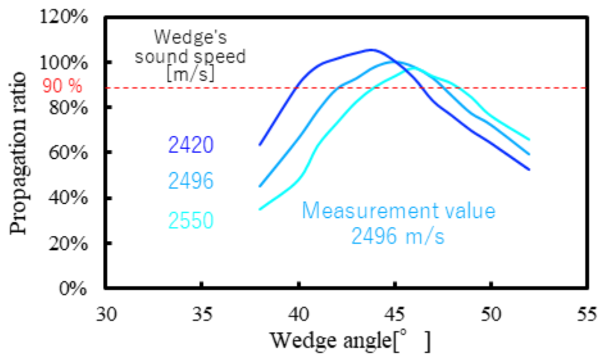

Fig.5 Propagation rate vs. wedge angle.

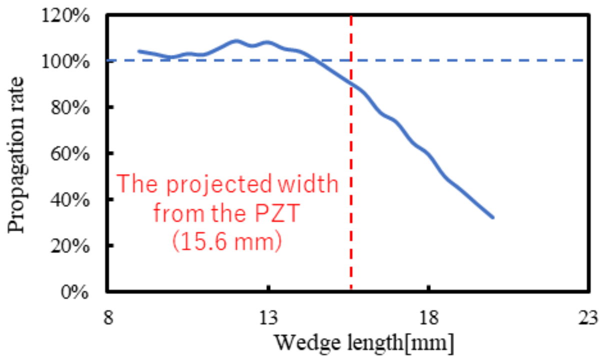

Fig.6 Propagation rate vs. bonding length.