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Position detection and remote controls powered by micro whistles☆

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ABSTRACT

This paper describes the design and detection of mechanically actuated micro whistles not equipped with any electronics. When actuated, the micro whistle generates an ultrasonic tone above the audible range. A set of three or more microphones in the near record this tone and the position of the whistle is calculated from the differences of the arrival times of the acoustic signals at the microphones. In experiments the positions of whistles were measured in a 2 m × 2 m area with an accuracy of less than 10 cm. Besides this, micro whistles have been employed as remote controls such as switches for room light or air conditioning.

The micro whistles have been fabricated by ultrasonic hot embossing of thermoplastic foils at low-cost and their overall size is approximately 1 cm. The paper also describes how to overcome obstacles such as accidentally generated ultrasonic noise, frequency shifts due to changing activation forces of the whistles, and distinguishing the signals of different whistles.

1. Introduction

Only a few papers are found on the detection of persons or objects in rooms [1–5]. Most of them require battery powered electronics on the movable object or person. This paper describes how the position of objects not equipped with any electronics but only with mechanically actuated micro whistles (see Figs. 1 and 2) can be detected by microphones mounted in a room. When actuated, the micro whistles generate a tone in the ultrasonic range above 20 kHz which cannot be heard by humans. The arrival time of the tone is recorded by three or more microphones in the near and the position of the whistle is calculated from the time differences by trilateration. This way, e.g., the moving of persons wearing shoes equipped with micro whistles (cf. Fig. 3) can be observed and help can be called when an elderly person stops regular moving. Besides this, micro whistles can be employed as remote controls such as switches for room lights which can be placed just at any place in the room and without any access to a power supply. A signal is generated by pressing a bellow providing an air stream which causes one or more tones. The signal is detected by a microphone in the room and triggers the desired switching.

This paper describes working principle and fabrication of micro whistles and the obstacles which need to be overcome achieving a reliably working system. It was already described in another publication that the resonance frequency generated by a whistle is a function of the force with which the bellow is pressed [6]. Besides this, ultrasonic signals generated by accident and reflected signals shall not affect performance and it is desirable to distinguish between signals generated by different whistles.

1.1. Micro whistles

Micro whistles have been developed for generating ultrasonic signals in remote controls without batteries and electronics [6]. The whistles consist of a resonance room and a bellow producing an air flow through the whistle when pressed with a finger (cf. Fig. 1). The typical duration of the sound signals emitted by micro whistles is around 10 ms. The whistles are 1.5 mm wide and 0.7 mm high (0.25 mm in the narrowing). The total length ranges from 10.5 to 13 mm. The inlet duct and the narrowing in total are 8 mm long. The frequency of the tone generated by a whistle can roughly be adjusted by the length of the resonance room. The frequencies generated are in the range of 18 kHz to approximately 35 kHz. The amplitude of the sound (in terms of sound pressure) produced by some whistles with different nominal frequencies and actuated with a silicone bellow or a push button from polyvinylchloride (PVC) (see below) is provided in Table 1:

1.2. Fabrication

The whistles were produced from thermoplastic plates by ultrasonic hot embossing and welding [6,7]. The inverse of resonance room, narrowing, and inlet area were milled as protruding micro

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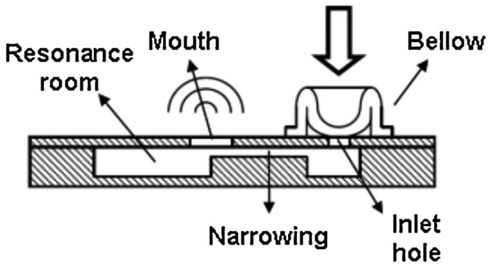

Fig. 1. Cross-section of a micro whistle.

Table 1
Sound pressure level (SPL) of whistles with different nominal frequencies. The value "max" corresponds to the highest RMS value with a time weighting of 125 ms, and peak is the highest SPL value registered, over 30 manual pulsations at 1 m distance. The sound meter employed was a Norsonic SPM 116, with a weighting filter "C".

	PVC push button		Silicone bellow	
	Max SPL	Peak SPL	Max SPL	Peak SPL
18.5 kHz	–	–	59.2 dB	77.1 dB
21.5 kHz	62.8 dB	84.7 dB	–	–
24 kHz	56.8 dB	79.6 dB	53.7 dB	70.4 dB
28 kHz	55.5 dB	73.1 dB	51.2 dB	58 dB

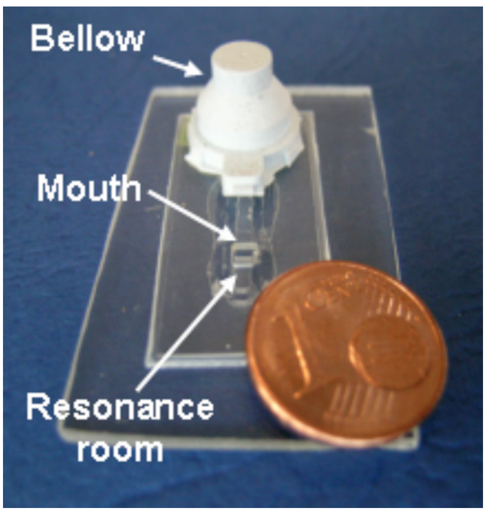

Fig. 2. Micro whistle fabricated from 2 PMMA plates, 10 mm and 1 mm in thickness, respectively.

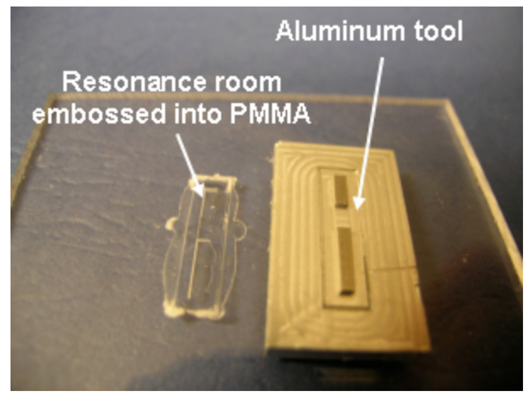

Fig. 4. Aluminum tool employed for ultrasonic hot embossing and PMMA base plate with embossed resonance room, narrowing, and inlet area.

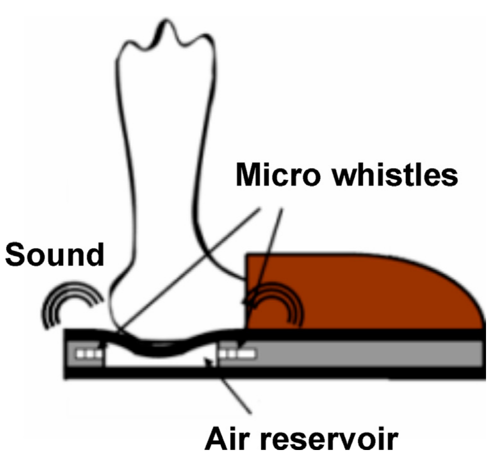

Fig. 3. Micro whistles in a shoe.

structures into an aluminum plate, 40 mm, 60 mm, and 4 mm in width, length, and thickness, respectively, serving as a tool (cf. Fig. 4). The tool is placed onto an anvil and covered by a base plate from polymethylmethacrylate (PMMA), 4 mm in thickness (Fig. 5a). The PMMA plate is pressed onto the tool at 44 kN by the sonotrode of a commercially available ultrasonic welding machine, and the ultrasonic vibrations generated by the machine (15 μm amplitude during 0.95 s) cause friction between the protruding structures of the tool and the PMMA plate (Fig. 5b). The friction heat melts locally the PMMA which is adapting to the shape of the micro structures on the tool. Ultrasonic hot embossing is completed after 5 s and the PMMA base plate is removed from the tool (Fig. 5c).

Then a 1 mm thick PMMA plate is ultrasonically welded as a lid onto the base plate with the micro patterns. Ultrasonic welding is facilitated by so called energy directors encircling the cavities on the base plate (cf. Fig. 5d). The energy directors are shaped as a wall, 150 μm in width and 75 μm in height, with a triangular cross-section. During ultrasonic welding the energy directors are molten and provide a kind of glue between lid and base plate (Fig. 5e). Welding is performed similar as ultrasonic hot embossing, with

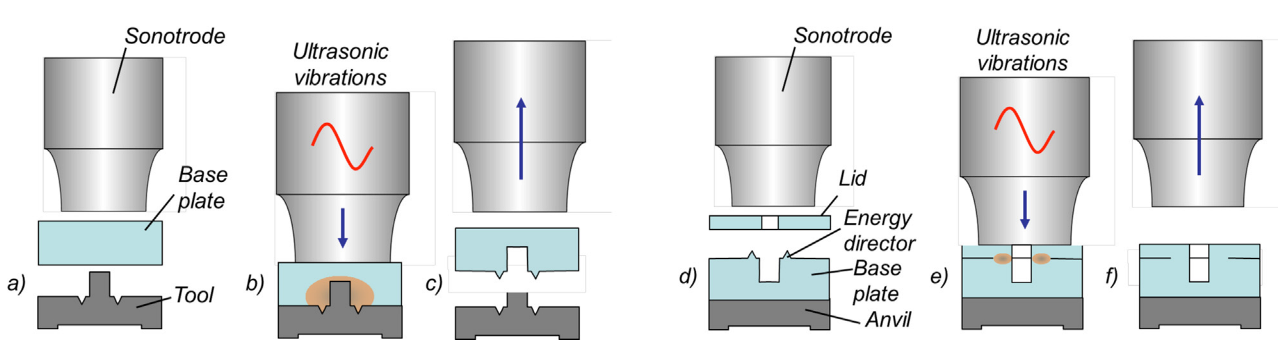

Fig. 5. Ultrasonic hot embossing of the whistle structure (a–c) and welding of a lid (d–f).