Journal of Technology and Social Science (JTSS)

Research on Sound Volume Improvement of Assembled Whistle

Yoshio Kurosawa[1, a,*], Makoto Ono [2,b]

[1]Faculty of Science and Technology, Teikyo University, 1-1 Toyosatodai, Utsunomiya City, 320-8551, Japan

[2]Raytrilogy Co.,Ltd, 2-20-6 Asakusabashi, Taito-ku, Tokyo, 111-0053, Japan

* Corresponding author

[a]< ykurosawa@mps.teikyo-u.ac.jp >, [b]< momo@raytrilogy.com >

Keywords: whistle, sound pressure level, fem, experiment

Abstract. We have developed a prefabricated whistle that is convenient to carry in order to call for help in the event of a disaster. Create by assembling business card-sized flat materials (Kent paper and coated paper used for ordinary business cards). This content has already been patented, but the volume (sound pressure level) was not sufficient. We will report the results of improving the sound pressure level and peak frequency by devising the internal structure and blowing method so that the rescuer can easily hear it. And, we will create a finite element model and introduce the results that qualitatively agree with the experimental results regarding the peak frequency.

1. Introduction

We have developed a prefabricated whistle that is convenient to carry in order to call for help in the event of a disaster. Create by assembling business card-sized flat materials (Kent paper and coated paper used for ordinary business cards). Fig. 1 shows the whistle before assembly (business card: left side) and after assembly (right side). The size is 91.0 mm in length and 11.0 mm on each side. This content has already been patented [1], but the volume was not sufficient. In this study, we introduce the results of a study in which the sound pressure level and peak frequency was improved by devising the internal structure and blowing method so that the rescuer could easily hear them.

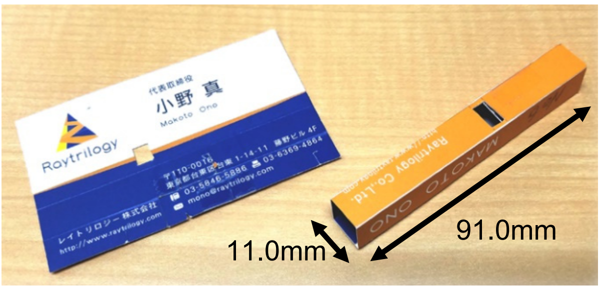


Fig. 1. The assembled whistle.

2. Experimental result

2.1 Whistle structure and experimental conditions

We examined the structure and dimensions that can produce a louder sound than the conventional product (Fig. 1). The mechanism that produces the sound of this whistle is an air lead instrument [2,3], similar to a general recorder. Fig. 2 shows the whistle of the prototype. Breathe in from the yellow frame in the Fig. 2 and make a sound. For the material of the whistle, we made a trial using coated paper and Kent paper, which are generally used for business cards. The thickness of the paper was about 0.3 mm and 0.33 mm, respectively. In the prototype, the distance from the hole on the top surface (red frame in Fig. 2) to the exit (double arrow in red in Fig. 2) was changed from 50.0 mm to 15.0 mm at 5.0 mm intervals. In addition, the gap through which the blown breath comes out (Fig. 3) is simply measured for three types of 1.0 mm, 1.5 mm, and 2.0 mm, and the sound pressure level, peak sound pressure, peak frequency, and frequency characteristics are measured. We compared, analyzed, and considered. The measurement was performed in a simple anechoic chamber with a glass wool board with a thickness of 50.0 mm attached to the wall and ceiling, and the measuring device was OROS24 (FFT analyzer) and Toyo Technica 378C01 (1/4 inch microphone). This time, the sound pressure level was measured at a position 400.0 mm away from the tip of the whistle.

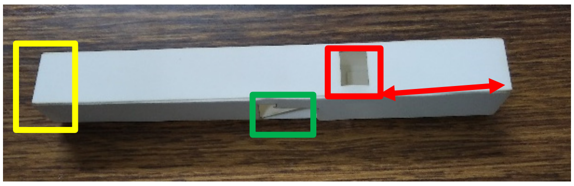


Fig. 2. Sample of the improved whistle.

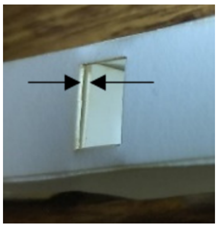


Fig. 3. The gap of the whistle.

2.2 Measurement result

Fig. 4 shows the measurement results of the sound pressure level of the conventional product. The distance from the hole on the top surface to the exit is 32.0 mm, and the gap where the breath blows out is 1.0 mm. The peak frequency was 1860 Hz, the peak sound pressure level was 68.1 dB, and the O.A. was 76.8 dB. Compared with some commercially available whistles, the target values were 86.0 dB for peak sound pressure and 95.0 dB for O.A. Fig. 5 to Fig. 8 show the measurement results of the improved product. Kent 4, 5, 6, 7 and 8 are made of Kent paper and the distance from the hole on the top surface is 35.0 mm, 30.0 mm, 25.0 mm, 20.0 mm, and 15.0 mm. Represents mm. There was no significant difference between Kent paper and coated paper. For all gaps, the loudest numbers (in red) in each test were 8 and 7 where the distance from the hole on the top surface to the exit was short. When the gap became large, it took a lot of breath to blow, and when the gap was 2.0 mm, it was difficult to make a loud noise. However, if the gap is 1.0 mm, the gap may be closed during assembly. The peak frequency increased as the distance from the hole on the upper surface to the exit (red double-headed arrow in Fig. 2) decreased. Table 1 summarizes the peak frequency, peak sound pressure, and O.A. The yellow fill in the table is a study product that has cleared the target.

In addition, Fig. 9 to Fig. 11 show the relationship between the distance from the hole to the exit and the peak frequency for each gap. The correlation was approximately negative. It is possible to design an approximate peak frequency from the approximate expression in the graph. In addition, the peak frequency was hardly affected by the gap.

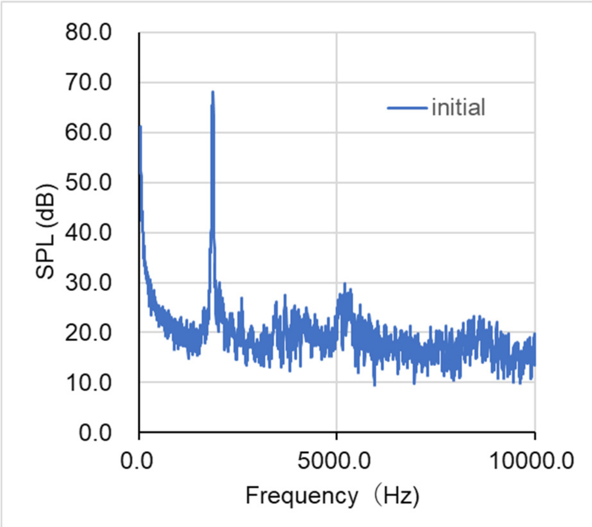


Fig. 4. Experimental result of initial whistle.

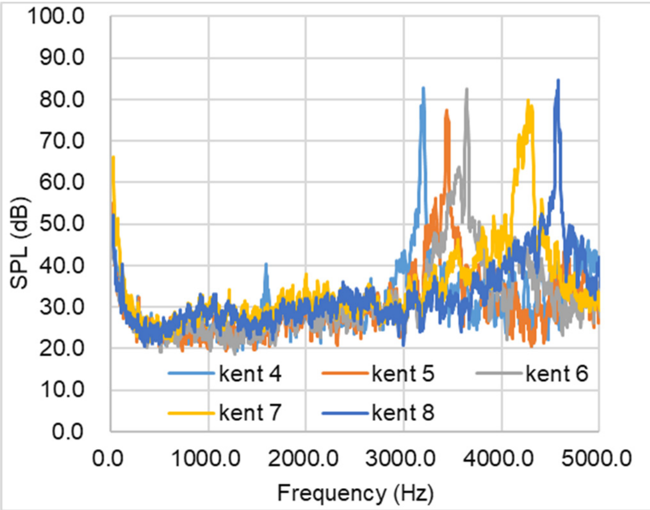


Fig. 5. Experimental results of improved whistle made by kent paper, gap of 2.0 mm.

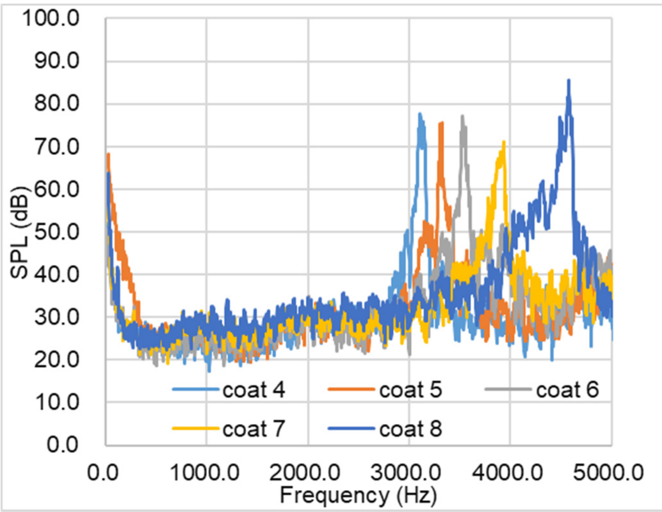


Fig. 6. Experimental results of improved whistle made by coated paper, gap of 2.0 mm.

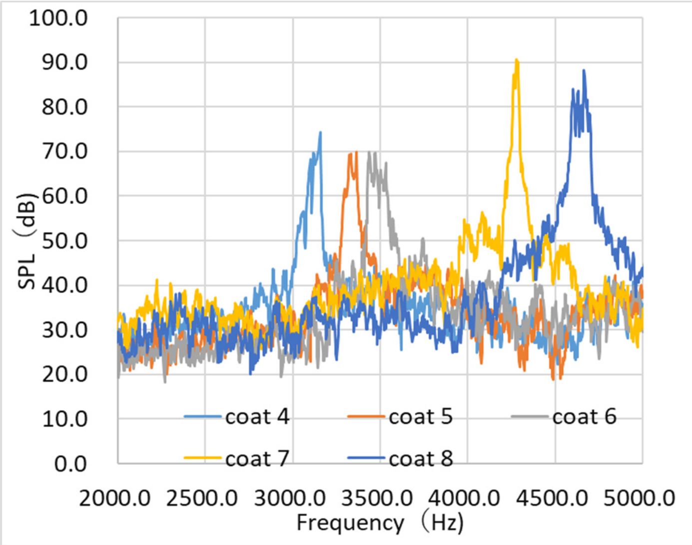


Fig. 7. Experimental results of improved whistle made by coated paper, gap of 1.5 mm.

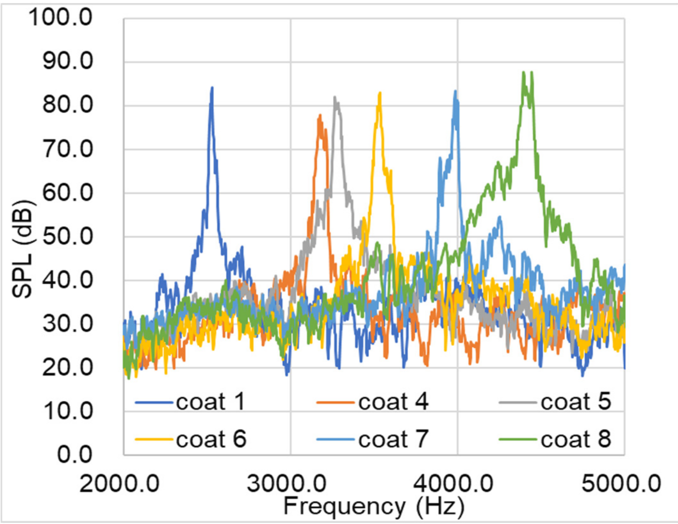


Fig. 8. Experimental results of improved whistle made by coated paper, gap of 1.0 mm.

Table 1 Measurement results of peak frequency and SPL and O.A.

	Gap 2.0 mm			Gap 1.5 mm			Gap 1.0 mm		
	Peak frequency [Hz]	Peak SPL [dB]	O.A. [dB]	Peak frequency [Hz]	Peak SPL [dB]	O.A. [dB]	Peak frequency [Hz]	Peak SPL [dB]	O.A. [dB]
coat 4	3110	77.8	85.5	3160	74.3	81.2	3180	77.9	85.6
coat 5	3320	75.7	83.0	3360	69.8	79.3	3270	82.0	89.7
coat 6	3530	77.2	84.2	3470	74.6	83.0	3530	83.1	89.0
coat 7	3930	71.2	80.7	4280	90.5	96.7	3980	83.4	88.5
coat 8	4580	85.7	92.1	4670	88.2	95.1	4390	87.7	96.0

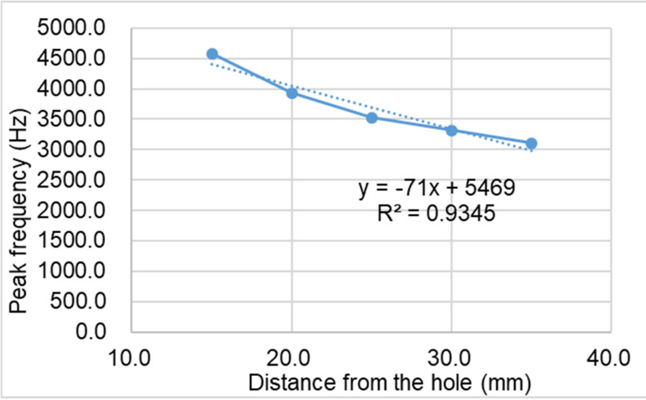


Fig. 9. Relation with peak frequency and distance from the hole on the top to the exit, made by coated paper, gap of 2.0 mm.

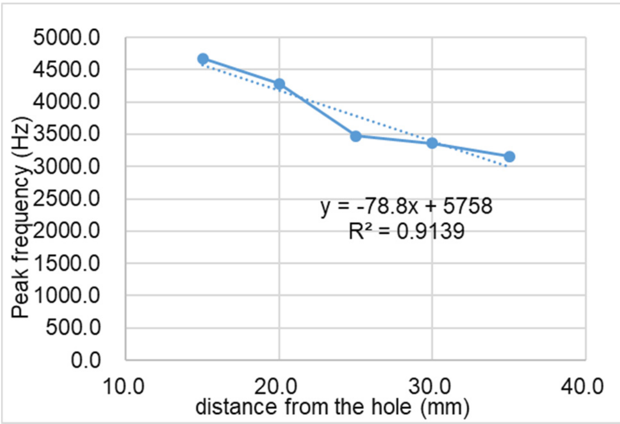


Fig. 10. Relation with peak frequency and distance from the hole on the top to the exit, made by coated paper, gap of 1.5 mm.

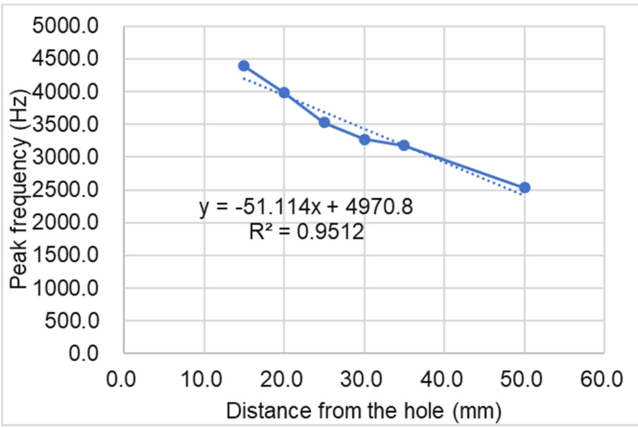


Fig. 11. Relation with peak frequency and distance from the hole on the top to the exit, made by coated paper, gap of 1.0 mm.

2.3 Acoustic analysis using a finite element model

We will introduce the results of acoustic analysis by creating a finite element model of this whistle. Fig. 12 shows the finite element model created this time. The number of elements is 457196 at a pitch of 0.5 mm. The sound source was set in the part where the breath of the upper hole collides (yellow line in the Fig. 12), and the upper hole and the right breath outlet were set to non-reflective condition (semi-infinite space). This time, only acoustic analysis was performed, and fluid analysis was not performed. Fig. 14 shows the results of calculating the sound pressure level at a point 400.0 mm away from the breath outlet, as in the experiment, by creating three models with different distances from the hole on the top surface to the outlet (Fig. 13). The absolute value of the sound pressure level was different from the measurement result due to the difference in the sound source, but the peak frequencies were almost the same. Two acoustic modes (2400.0Hz, 4400.0Hz) at peak frequencies are shown in the Fig. 14. Fluid analysis, which compares sound pressure levels at peak frequencies with the same amount of breath, is a topic for the future.

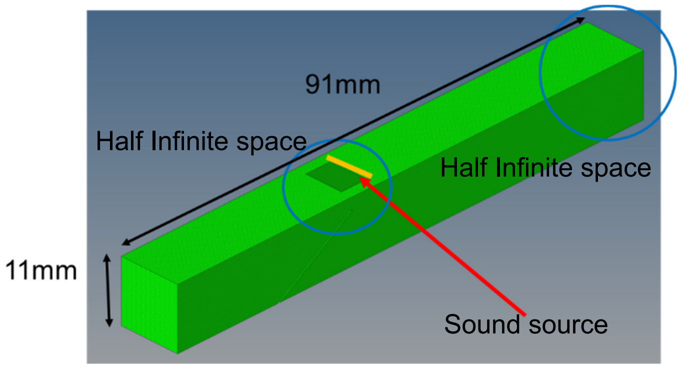
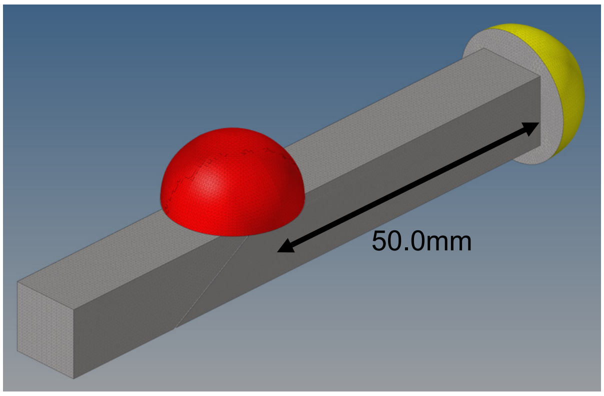
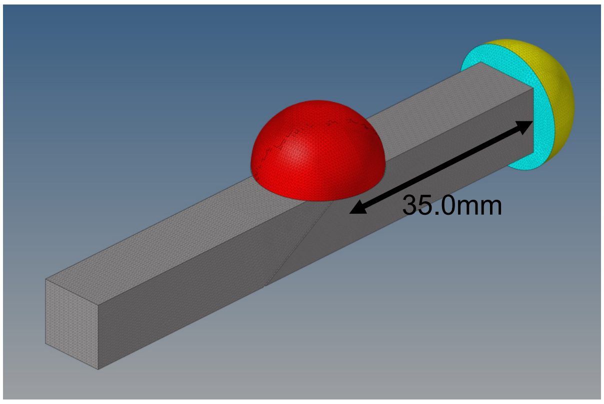


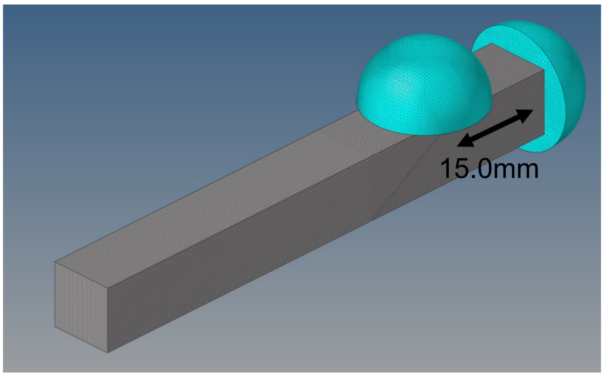
Fig. 12. FE model of whistle.



(a) The distance from the hole on the top to the exit is 50.0 mm



(b) The distance from the hole on the top to the exit is 35.0 mm



(c) The distance from the hole on the top to the exit is 15.0 mm

Fig. 13. FE models of 3 types of whistles.

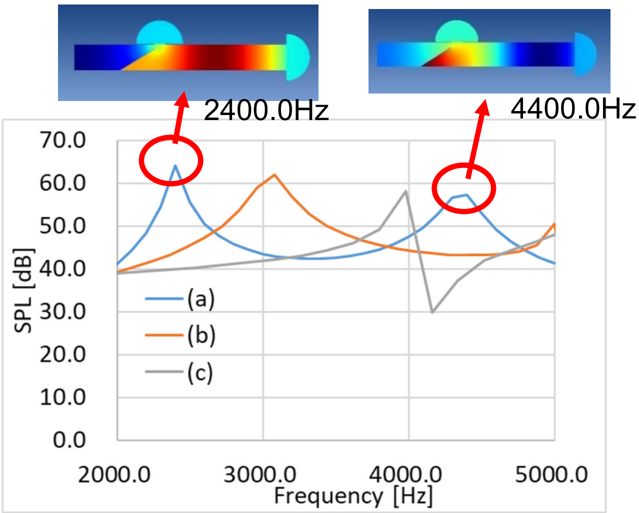


Fig. 14. Calculation results of sound pressure level for 3 type whistles.

2.4 About the examination result of how to blow

Fig. 16 and Table 2 show a comparison of the sound pressure levels when the side holes (green frame in Fig. 2) are completely closed and when they are slightly opened (Fig. 15). Both coat 7 and 8 made a louder sound when opened slightly than when the sides were completely closed. When it was closed, the target value could not be cleared. When the sides were completely closed, the peak frequency was slightly lower than when the sides were opened a little. However, there are individual differences in the whistle itself and variations depending on the person who blows it (some people make a louder sound when it is completely closed), so this is a topic for future study.

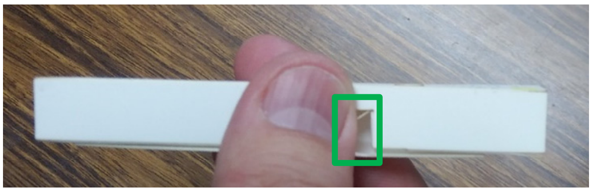


Fig. 15. Setup for not closing a hole in the side.

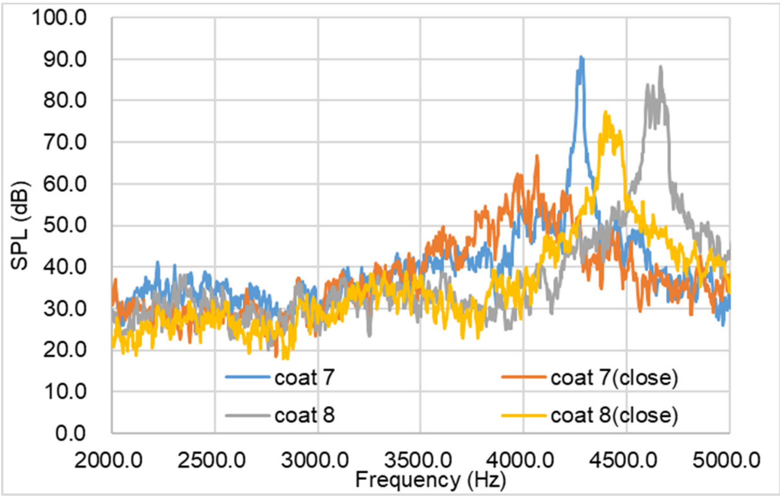


Fig. 16. Comparison of SPLs when closing hole and not (coated paper, gap 1.5mm).

Table 2 Comparison of peak frequency and SPL and O.A.

	Coat 7	Coat 7 (Close)	Coat 8	Coat 8 (Close)
Peak frequency (Hz)	4280	4070	4670	4420
Peak SPL (dB)	90.5	66.8	88.2	77.5
O.A.(dB)	96.7	77.3	95.1	86.5

Fig. 17 shows a comparison between the conventional product and coat 7, which has the highest sound pressure level. The sound pressure level at the peak frequency was improved from 66.8 dB to 90.5 dB, and O.A. was improved from 77.3 dB to 96.7 dB. The peak frequency increased from 1880 Hz to 4280 Hz, but there was no problem with audibility.

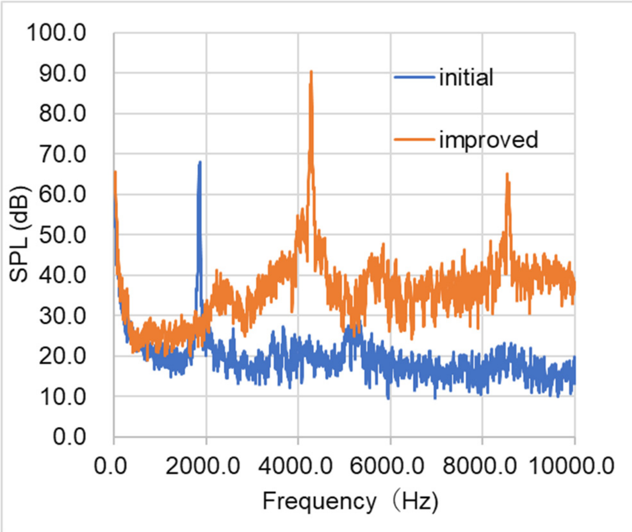


Fig. 17. Comparison of SPL initial and improved whistles.

3. Summary

We developed a portable whistle to call for help in the event of a disaster, but the volume was not sufficient. To make it easier for rescuers to hear, we conducted experimental measurements and examined the internal structure and blowing method using a finite element model.

As a result, at a distance of 400.0 mm, the conventional product was 76.8 dB, but it was improved to 98.4 dB. Furthermore, we were able to derive an experimental relational expression between the distance from the hole to the exit and the peak frequency. In addition, the gap between the breath passages is related to the amount of breath (easiness to blow), and it was judged that about 1.5 mm is optimal in consideration of the balance with the volume and the variation at the time of assembly. There is no particular knack for blowing, and even beginners can make a sufficiently loud sound, but it was discovered that the sound pressure level can be improved by closing the holes on the side.

References

[1] M. Ono, ***Japanese Patent,*** No.6358725.

[2] ***Acoustic of musical instruments***, Y. Ando, Ongaku no Tomosya (Tokyo, Japan), 1996.

[3] ***The Physics of Musical Instruments***, N. H. Fletcher and T. D. Rossing, Springer-Verlag (Tokyo, Japan), 2002.

[4] Y. Kurosawa, M. Ono, “Study for Improving Volume of the Assembled Whistle”, ***Proceedings of ICTSS2021*** (Kiryu, Japan) December 2021.