Research on a Noise Control Device

(3rd report, Fundamental Design of the Device (2))*

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The structural design method of the noise control device was described in the 2nd report and it is possible to design the structure of the device by this method. But it is necessary to decide how to place the device for a noise source when it is applied. That is, an appropriate position for the noise source is required in order to obtain better noise reduction effect.

Therefore, the design method for placing the device was considered through some model experiments in an anechoic room and the field, and the prediction method of the sound pressure level in the case of using the device with a barrier was investigated.

The results are described in this paper.

Key Words : Sound, Noise Control, Noise Reduction, Barrier, Set Design, Interference Zone

1. Introduction

The noise control device is a structure with a sound phase lag circuit and it is used to reduce airborne noise such as machine noise, construction noise and traffic noise.

In the 1st report⁽¹⁾, the principle of the noise control device was described, and was shown that a great noise reduction effect was produced by sound refraction and sound interference. The interference region was predicted by an acoustic geometrical drawing in the 1st report. In the 2nd report⁽²⁾, the structure factors of the device and the pipes composed of the device are studied. However, when the device is used for noise reduction, it is necessary to determine how to place it with a barrier and it is very important to adjust the relative distance between the device and a noise source appropriately.

Hence, the authors wish to report on the appropriate position between the device and a noise source

and the effect of the device with a barrier from their investigation by some model experiments and field tests.

Fig.1 Fundamental principle of the device

2. Fundamental Design of the Position

The largest problem in the application of the device is the relative position of a noise source, that is, the horizontal distance and vertical distance from the noise source.

To investigate this problem, we measured a change in the noise reduction effect of the device in Fig.3 with the distance from the noise source, as shown in Fig.2. Fig.2 depicts the reference position of the device and the noise source (a speaker), and ΔX and ΔY indicate the horizontal distance change and the vertical distance change from the noise source, respectively.

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Fig.2 Experimental arrangement

Fig.3 Device (type 1)

Positive ΔX means that the device approaches the source and positive ΔY means that the device moves upwards. When we moved the device vertically, we moved the source (a speaker) relatively, and we measured the sound pressure levels at points O1, O2, O3 in some experiments. The noise source radiated a white noise and a floor was covered with 50mm thickness glass wool in order to absorb refracted waves from the device.

2.1 Horizontal position

Fig.4 shows the noise reduction data at O2 which was located in the center of the interference region bounded by two-dot chain lines. ΔX are 90mm, 0mm, -90mm, -180mm and -360mm. It is seen from Fig.4 that the noise reduction effect decreases when the distance between the device and the noise source increases at almost all frequency bands, whereas

Fig.4 Noise reduction at O2
(horizontal distance)

it decreases when the device is too close to the source. From this fact, it seems that the interference region produced by the device is closely related to the relative position of the device and the source, and an appropriate horizontal distance must exist. As described in the 1st report, the noise reduction effect in the interference region is almost constant and great, but it decreases extremely outside the interference region.

Therefore, the best way to determine the appropriate horizontal distance between the device and the source when a receiver and a frequency band are given is to calculate the position of the device where the receiver is located in the most effective part of the interference region.

2.2 Vertical position

The noise reduction data with the change of ΔY are given in Fig.5, where ΔY are 0mm, 40mm, -210mm and -420mm. When $\Delta Y = -210$ mm and -420mm, a noise source (a speaker) is moved upwards, therefore, the receiver is relatively moved upwards, too.

Fig.5 indicates that the noise reduction effect at O2 in the interference region does not change when the device is moved upwards, but it extremely decreases when the device is moved downwards. These results show that the position of the interference region changes and O2 is located in the neighborhood of the upper boundary line of the interference region, because a great noise reduction can be obtained if O2 is in the center of the interference region.

Therefore, we can determine the appropriate vertical distance from the source if we can put the receiver in the neighborhood of the center of the interference region by use of the acoustic geometrical drawing.

Fig.5 Noise reduction at O2
(vertical distance)

2.3 Effects for a point source and a line source

The noise reduction effects were measured at O_1 , O_2 and O_3 using the device shown in Fig.6 in order to know the difference between a point source and a line source. The point source was a full-range speaker and located at the center of the device length, and a line source was composed of some full-range speakers which were located with a separating distance 200mm. The results are summarized in Fig.7 and it seems that the noise reduction effect for the line source is nearly equal to the noise reduction effect for the point source.

Fig.7 Noise reduction effect (source type)

Fig.6 Device (type 2)

3. Effect of the Device with a Barrier and its prediction Method

Generally, the noise control device is used with a barrier lest refracted sound waves by the device should reach a receiver where the noise has to be reduced. Furthermore, the noise reduction effect behind a barrier is increase because the diffracted noise from the top of the barrier is decreased by the device. We call the device combined with a barrier the noise control system.

3.1 Fundamental model test in an anechoic room

The noise reduction effect of the noise control system shown in Fig.8, which was measured in an anechoic room, is shown in Fig.9. There is a receiver at O and the device used for this experiment shown in Fig. 6. A large effect of noise

Fig.8 Arrangement of the device and a barrier

reduction is observed in Fig.9, but when the radiation side of the device is closed, the noise reduction effect is decreased and becomes nearly equal to the effect of a barrier. Namely, when the radiation side of the device is closed, the device works only as a double barrier, therefore, the interference region cannot be generated by the device and a great noise reduction effect cannot be obtained. In Fig.10, the noise reduction effect of only the device near the top of a barrier is shown. It is confirmed that the noise

Fig.9 Noise reduction at O (combination of the device and a barrier)

Fig.10 Noise reduction effect at P

reduction effect of the noise control system is approximately equal to that of the device itself at the top of the barrier plus that of the barrier.

In Fig.11, the noise reduction effect with a change of the horizontal distance between the device and a barrier is shown.

Fig.11 Noise reduction effect with the change of X

It illustrates that the noise reduction effect begins to be decreases at a low frequency band when the distance is decreases. Because it seems that refracted sound waves produced by the device are interrupted by the barrier before direct sound waves and refracted sound waves thoroughly interfere with each other. By comparing the vertical distance between the device and the barrier with a sound wave length, it is known that the distance should be more than a half wave length if we want to obtain good effect of noise reduction.

3.2 Field test of the device

If a receiver is far from a noise source, it is impossible to measure the noise reduction at an anechoic room, therefore, it should be measured in the field, and it was measured in the situation of Fig.12. The geometry of the device used for this experiment is the same as that of Fig.6, but the device is composed of 50mm² pipes (5mm thickness) made of concrete, and the device which has

Fig.12 Arrangement of field test

pipes tilted at an angle $5/18\pi$ (rad) is placed with a barrier which is 1.9m from the floor and made of 20mm thick lauan plywood coated with absorptive material on the noise source side. The sound pressure levels at O in three cases are shown in Fig.13. That is, they are only a

Fig.13 Sound pressure level at O

barrier, a noise control system (the device with a barrier) and a noise control system closed at the sound radiation side (a double barrier).

It is seen that the sound pressure levels are increases at O and O' when the sound radiation side of the noise control system is closed, namely, the noise reduction is decreased. In this case, the noise control system works only as a double barrier.

In fig.14, the noise reduction effect of the device alone is indicated at the point P near the top of the barrier. If this noise reduction is subtracted from the sound pressure level in the case of only a barrier, the sound pressure level of the device with a barrier, namely, of the noise control system is obtained.

Hence, it is confirmed from this fact that the noise reduction effect of the noise control system is approximately equal to the sum of the noise reduction of the device itself and that of only a barrier as

Fig.14 Noise reduction at P (only device)

verified in the case of the experiment in an anechoic room. Furthermore, it is known that a great noise reduction effect is obtained at a far receiver.

3.3 Noise reduction calculation method of the noise control system

From the above result, it is considered that the noise reduction effect of the noise control system may be expressed by

$$\Delta L = \Delta L_p + \Delta L_w \quad \text{.....Eq.(1)}$$

where

ΔL = noise reduction by the noise control system
(the device with a barrier)

ΔL_p = noise reduction by only the device near the top of a barrier in the interference region

ΔL_w = noise reduction by only a barrier

Since ΔL_w in relationship (1) can be easily calculated based on a generally used relationship, the noise reduction effect of the noise control system can be determined at an arbitrary position if ΔL_p can be known, for example, by some model experiments in an anechoic room.

Furthermore, if the sound power level of a noise source is known, the sound pressure level at a receiver can be also calculated as follows.

When a noise source is a point source,

$$SPL_i = PWLi - 20 \log r - 8 - \Delta L_{wi} - \Delta L_{pi} \quad \text{.....Eq.(2)}$$

where

SPL_i = sound pressure level at a frequency band i (dB)

PWL_i = sound power level at a frequency band i (dB)

ΔL_{wi} = $10 \log(0.2 + \frac{2s}{\lambda}) + 12.5$
noise reduction by only a barrier (dB)

ΔL_{pi} = noise reduction by only the device near the top of the barrier in the interference region (dB)

λ = wave length

r = distance between source and receiver

S = point source

R = receiver

δ = path difference as shown in Fig.15

If SPL_i' is A-weighted SPL_i , the overall SPL (dBA) will be given as follows.

$$SPL = 10 \log \left(\sum_i 10^{\frac{SPL_i'}{10}} \right) \quad (\text{dBA}) \quad \text{.....Eq.(3)}$$

Fig15 Relationship of a source and a receiver

4. Conclusion

When the noise control device is actually applied to a noise source, how to place it relative to the source and how to combine it with a barrier are very important, therefore, many model experiments and field tests were made for this purpose.

Consequently, it is necessary to select the arrangement design factors appropriately by the acoustic geometrical drawing method mentioned in the 1st report so that the interference region may be produced appropriately at a receiver because the interference region which generates a great noise reduction effect depends on the arrangement of the device, the noise source and the barrier.

In ordinary use, the noise control device is applied with a barrier lest refracted sound waves should reach a receiver, therefore, the noise reduction effect and the effect calculating method were investigated using the noise control system. As a result, it is recognized that the noise control system has a great noise reduction effect and the effect can be approximately calculated rather easily by using model experiment data collected in an anechoic room. In addition, it is shown that the sound pressure level and the A-weighted overall sound pressure level (dBA) at a receiver can be estimated from the relationships (2) and (3).

By study on the principle in the 1st report, study on the structural design in the 2nd report and study on the arrangement design in this report, it is made possible to apply the noise control device to a noise source. However, since more precise research is necessary for application of the device to given circumstances, the authors would like to continue study on a more appropriate design.

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6. References

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