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Improvement of construction machine noise

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ABSTRACT

This Study deals with the improvement of booming sensation inside the compartment of construction machine. Booming sensation is the hearing sensation caused by the existence of low frequency component below 500Hz and due to this component our ear drums are pressurized and feel pressurized feeling that is uncomfortable. In the first place, 6 construction machines were tested their degree of booming sensation and the worst one for this ranking is selected for improvement. Then, several factors are selected for improvement of booming sensation. Selected factors are fun noise, intake and exhaust noises. In order to test the effect of these factors to the reduction of booming sensation, each component noise was eliminated by the lead cover method. As a result, reduction of fan noise was most effective counter measure for the improvement.

Keywords: Booming sensation, Low frequency sound, Improvement, Fun noise

1. INTRODUCTION

At the construction site of buildings and that for the development of city area for example, many construction machines are used for moving earth and to move heavy materials for the constructions. Due to this, the inhabitants near the construction cite exposed to the noise emitted from the machines(1). In these days, the noise emitted from these machines becomes quieter and quieter in order not to affect the residents near the construction site. Together with the noise emitted to the outside, the compartment noise inside the cabin must be improved for the operators inside(2). Especially, if low frequency content of sound below 500Hz dominates inside the cabin, then the booming sensation reveals to the operator's hearing and felt annoyed. This paper describes the way how we reduce booming sensation that is felt uncomfortable inside the compartment.

For this purpose, we have conducted subjective experiment by using 6 medium size construction machine noises for the evaluation of booming sensation to decide the ranking of booming sensation. Then, to pick up the sound with worst ranking for booming sensation, we have conducted the second experiment for the improvement of booming sensation by modifying the original sound in various ways. The countermeasure introduced were reductions of cooling fun noise, intake and exhaust noises. And these effects were tested subjectively in a separate manor on one hand and the combined effects are also examined.

As a result, to reduce cooling fun noise for cooling the Diesel engine equipped for the power to activate oil pressure for the construction machine is most effective countermeasure for reducing booming sensation.

2. EXPERIMENT FOR RANKING OF BOOMING SENSATION

2.1 Test Sounds, Subject and Test method

Test sounds are 6 construction machine noises at no load and high idle condition for medium size construction machines, their weights are similar and 20tons class. Subjects participated this experiment were 19males and 2 females aged between 21 and 62 with normal hearings. Test was conducted inside the sound proof room and subject sits in front of the screen set 2m apart from the

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subject. In the first place, video image of the construction machine is projected on the screen by the LCD projector and construction machine noise was reproduced by the equalized headphone and woofer set in front of the subject to strengthen the low frequency sound with realistic impression. In this stage, subjects were asked to just watch the image and hear the sound. Then, next session, only sounds were reproduced with no image and subjects were asked to evaluate the booming sensation using score seat. They are asked to evaluate booming sensation in seven categories from 1 to 7 that are relates to not booming at all to strong booming.

2.2 Test result

The result was shown in Figure 1. as is shown in this figure, sound B is more booming among the 6 sounds. And the relation between the test result and booming index(3) was shown in Figure 2. The relation between the test result in booming sensation and booming index is good and the correlation is 0.903. On the other hand, relation between booming sensation and loudness(4) is not so high compared with that with the booming index In this case, correlation is r=0.617.

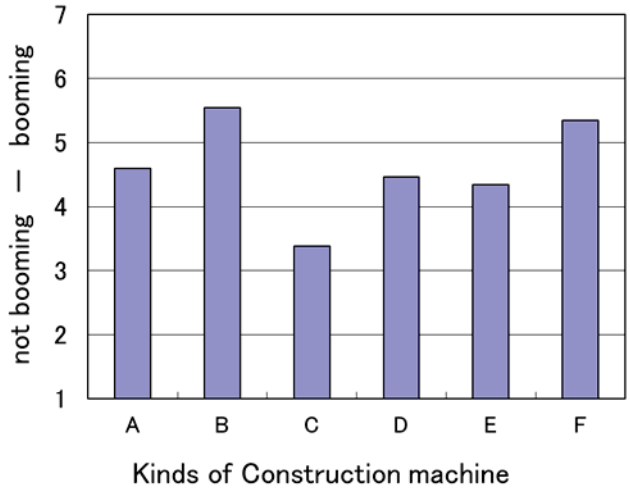
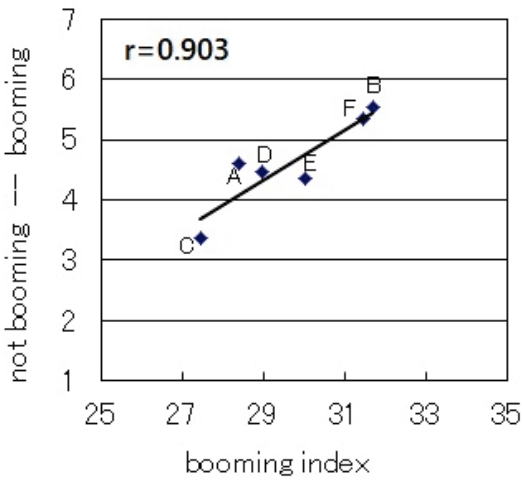


Figure - 1 result of ranking on booming sensation for 6 construction machines



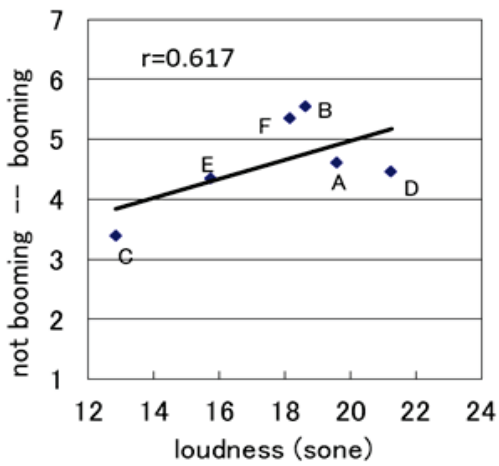


Figure – 2 booming sensation and booming index Figure -3 booming sensation and loudness

2.3 Select of the sound to improve

As a result of this experiment, we have chosen the sound B as the one to modify its booming sensation because this sound is more booming among the 6 sounds..

3. IMPROVEMENT OF BOOMING SENSATION ON SOUND "B"

3.1 Method for Improvement

As was shown in the previous chapter 2, test sound B is most booming sound among the 6 test sounds. In order to make sound B with less booming sensation, the original test sound was modified at the recording stage. The way we modified the sound B is as follows.

① Original sound without modification
② Elimination of cooling fun noise by elongation of inlet horse at the original fun position and the introduction of lead metal cover for the reduction of fun noise.
③ Elimination of exhaust noise by the lead metal cover of the exhaust muffler area.
④ Elimination of intake noise by the lead metal cover of the intake muffler area
⑤ Elimination of fun and exhaust noises
⑥ Elimination of fun and intake noises
⑦ Elimination of intake and exhaust noises
⑧ Elimination of fun noise and intake and exhaust noises.

FFT spectra of original sound B, and that of the elimination of fun noise is shown in Figure – 4. By the elimination of fun noise, broad band level reduction effect is observed according to see Figure -4. We could expect more effect for the improvement of booming sensation by this treatment.

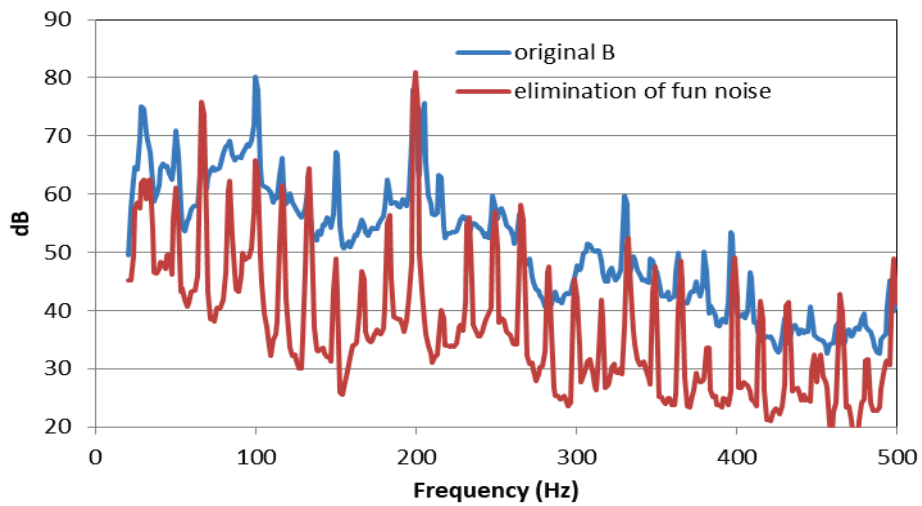


Figure – 4 FFT spectra of sound B and that of the elimination of fun noise

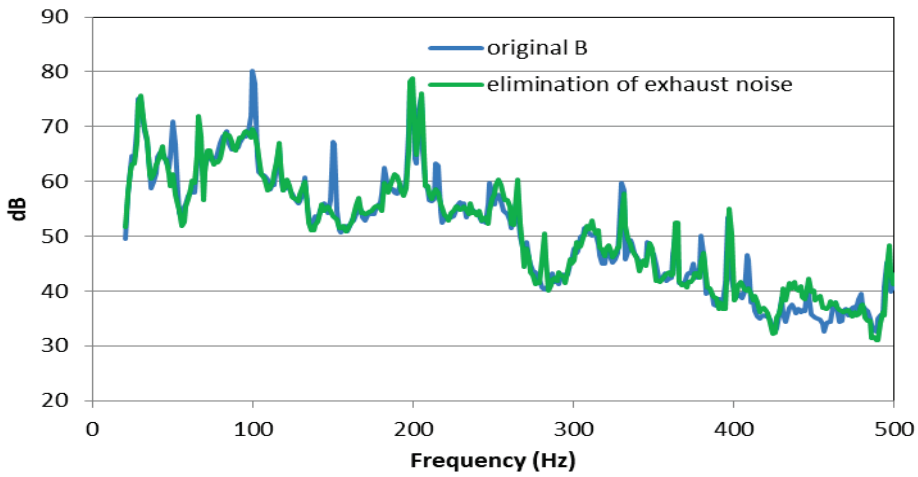


Figure – 5 FFT spectra of sound B and that of the elimination of exhaust noise

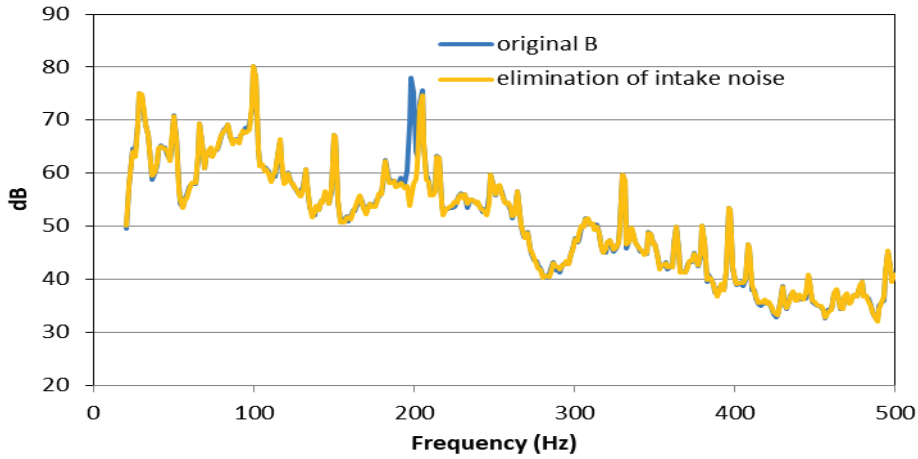


Figure – 6 FFT spectra of sound B and that of the elimination of intake noise

From Figure -5, we could two peaks around 100 and 150 Hz reduce their peak values by the elimination of exhaust noise. And by the elimination of intake noise, peak at the 200Hz reduced its peak significantly and as is shown in Figure – 6.

3.2 Subjective Evaluation of Sound B and its Variations

The method to represent sound to the subjects is the same as in the first test for the presentation of sound alone condition. And the subjects participated in this experiment are the same as in the first experiment. Again, subjects were asked to evaluate the booming sensation of test sounds in 7 categories from one to seven that related to not booming and booming.

Result of evaluation in booming sensation for the variation of sound B including its original was shown in Figure – 7.

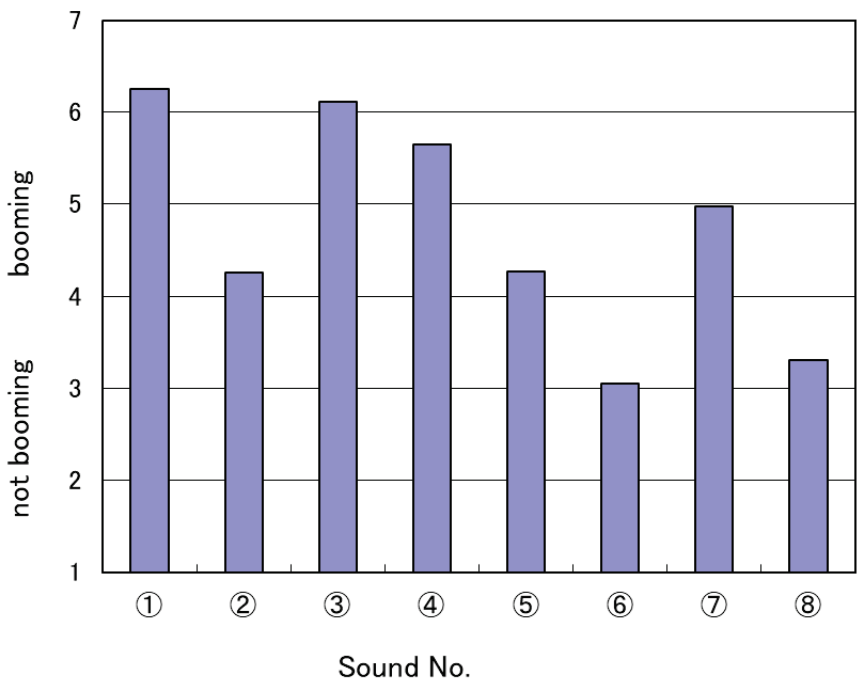


Figure – 7 Evaluation of booming sensation of sound B and its variations

According to the test result, if one countermeasure is selected, then elimination of fun noise is

most effective for the reduction of booming sensation(①) and the second one is elimination of intake noise(④) and the last one is elimination of exhaust noise(③). Combined effect by the several treatments taking together is the most for the elimination of fun and intake noise together(⑥) and this is close to the three treatments together(⑧), namely the elimination of fun, intake and exhaust noise. The least effect is observed by the combined effect of the elimination of intake and exhaust noises together(⑦) elimination of fun and exhaust noise together is close to the elimination of fun noise alone(⑤).

The relation between booming sensation of test sounds and booming index is shown in Figure – 8 and that with the loudness is shown in Figure – 9.

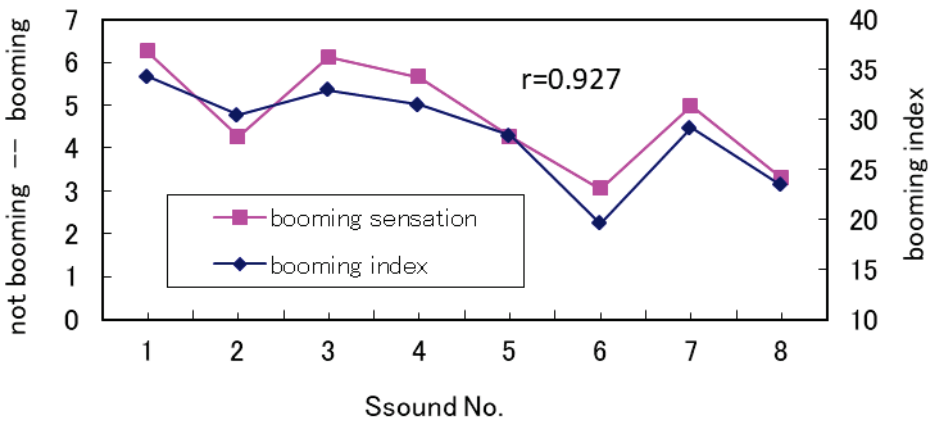


Figure – 8 relation between booming sensation of test sound and booming index

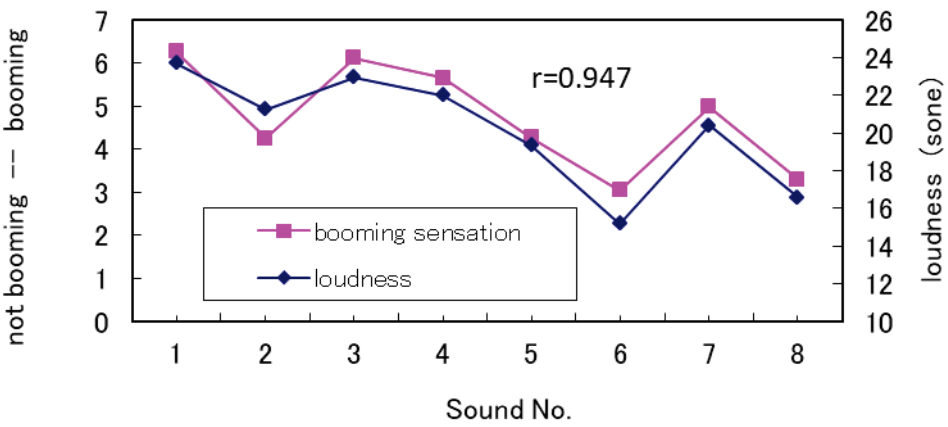


Figure – 9 relation between booming sensation of test sounds and loudness

The evaluation of booming sensation of the test sounds, namely, sound B and its variations are well collated with the booming index and loudness.

The result of evaluation on booming sensation is compared with the sound energy ratio, namely, sound energy of the sound variations were divided by that of the original sound B. We could have high correlation with this expression, r=0.9246. Namely with the treatment of sound B, sound energy of the treated sound reduced and if the energy reduction is more then the sound becomes less booming.

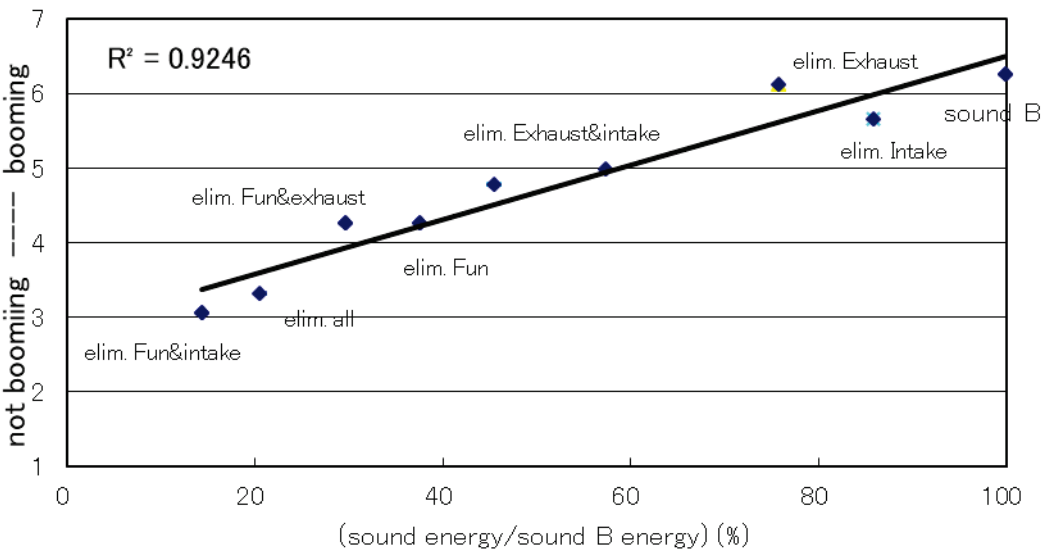


Figure – 10 relation between booming sensation of test sounds and sound energy ratio

4. CONCLUSIONS

The evaluation of booming sensation of cabin noise of medium size construction machines was conducted under the condition of high idle no load condition. In the beginning of the experimental stage, we have compared 6 construction machine noises for the ranking of booming sensation to pick up most booming sound among the six test sounds. Then, the most booming sound was selected for improvement.

In order to find the way to reduce booming sensation of cabin noise inside the compartment of construction machine, three treatments were selected, namely, elimination of cooling fun noise, elimination of intake noise and that of exhaust noise. We also tested combined effect of the simultaneous treatments such as elimination of fun and intake noises etc.

As a result, following conclusions were obtained..

1. Result of booming evaluation obtained for ranking which sound is more booming with the others related well with the booming index. Our current result shows that correlation between evaluation and booming index is 0.903 while the that with the loudness is 0.617.
2. For the improvement of booming sensation of cabin noise inside the compartment, we have introduced three treatments, i.e. elimination of cooling fun noise, eliminations of intake noise and that of exhaust noise from the original sound.
3. As a result, elimination of fun noise is the most effective counter measure for the reduction of booming sensation.
4. The reason why this effect is obtained is that this treatment realizes broadband level reduction effect along the frequency band from 20Hz up to 500Hz.
5. Elimination of intake noise is second effective countermeasure for the reduction of booming sensation.
6. The least effect is observed for the treatment of exhaust noise elimination but it still has some effect.
7. Combined effect by introducing two or three counter measure simultaneously is more effective for the reduction of booming sensation. Especially, the most efficient combined effect is observed by the combination of fun noise and intake noise eliminations.

8. The result obtained by introducing 3 treatments correlated well with the energy ratio value. This means that by the treatment, the modified sound reduces it sound energy to some extent.

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