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A STUDY ON THE HYDRAULIC NOISE REDUCTION OF EXCAVATOR

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Abstract

The hydraulic noise is the one of the main noise sources that affects the noise levels at cabin and outside of the excavator. The pressure pulsations induced by the hydraulic system such as pumps, hoses, and valves, are transmitted to the structure-borne noise of the connected structures and radiated to the airborne noise of the excavator. Therefore, in order to control the hydraulic noise, the flow velocity and pressure fluctuations of hydraulic system and the structure-borne noise of the connected structures have to be reduced by the noise control measures and the design changes of hydraulic system. In this study, the performances of the hydraulic silencer and side branch resonator as noise control devices have been analyzed and tested on real hydraulic excavator to reduce the propagation of fluid-borne noise. In addition, damping materials and dynamic absorbers have been applied to lower the structure-borne noise of the adjacent structures. As a result, the sufficient noise reduction at cabin and outside of the excavator has been obtained by the application of the countermeasures for the hydraulic noise.

INTRODUCTION

The hydraulic systems are very often used in construction equipment because they may generate the big forces and moments in an instant. The hydraulic noise generated by the hydraulic systems is the one of the main noise sources that affects the noise levels at cabin and outside of the excavator, and recently, the noise emission of hydraulic components is increasing according as the power density of hydraulic systems is being high. Many industrialized countries have regulations that restrict the noise levels in the workplace and environment, and the emphasis on quieter equipment is growing daily.

To reduce the hydraulic noise, this paper considers the attenuator to lower the pressure pulsations and the countermeasures to reduce the structure-borne noise radiated to the airborne noise of the excavator. In addition, the experimental results measured at the real hydraulic excavator are suggested.

THE GENERATION AND TRANSMISSION OF HYDRAULIC NOISE

The dominant noise source of hydraulic system is the pump. The pressure pulsations that are induced by operation of the pump create the fluid-borne noise, which causes all downstream hydraulic components to vibrate. And the vibrating hydraulic system such as pumps, hoses, and valves, transmits the structure-borne noise to the connected structures, and finally, the vibration of adjacent structures results in the air-borne noise at cabin and outside of the excavator. Therefore, in order to control the hydraulic noise, the pressure pulsations of hydraulic system and the structure-borne noise of the adjacent structures need to be reduced by the noise control measures and the design changes of hydraulic system.

THE CHARACTERISTICS FOR THE OBJECT OF EXPERIMENT

The objects of experiment are the small-sized hydraulic excavators and the noise sources such as diesel engine, cooling fan, and hydraulic pump, are set in engine room located at the rear of cabin. And the hydraulic hoses and MCV(main control valve) are located near the cabin. Therefore, the hydraulic noise greatly affects the noise level of cabin as well as outside. In the case of the 1st model, the excitation frequencies of the pressure pulsations generated by the pumps are 383Hz and its harmonics at the commonly used engine operating RPM. And, in the case of the 2nd model, the excitation frequencies are 184Hz and its harmonics.

The noise levels and noise contribution at cabin and outside of the 1st excavator are shown in Figure 1 and the noise level at outside is the average value that is measured at the six measurement points on hemisphere. The noise levels of 400Hz and 800Hz octave band, which are the 1st and 2nd order hydraulic noise induced by hydraulic system, are dominant at the cabin and outside of excavator.

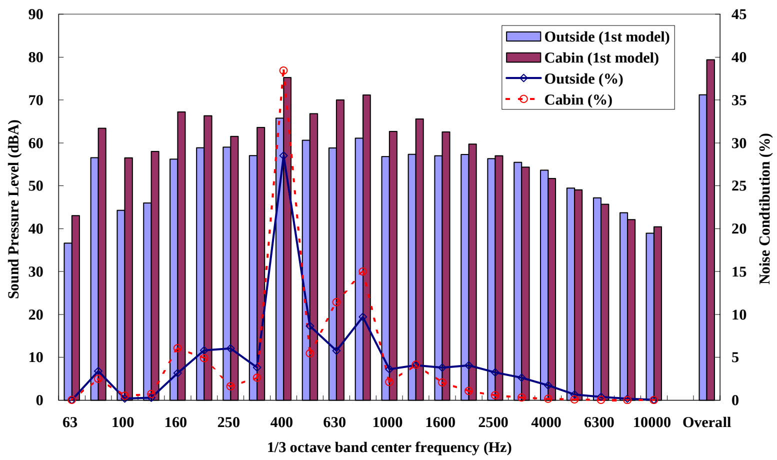

Figure 1 The noise levels and noise contribution at cabin and outside

REDUCING FLUID-BORNE NOISE

The fluid-borne noise due to pressure pulsations can be minimized through the design change and appropriate selection of hydraulic pump, however it cannot be completely eliminated. Therefore, to reduce the propagation of fluid-borne noise, the side branch resonator and reflection silencer are applied to the real hydraulic excavator.

Applying the side branch resonator to the 1st model

To reduce the pressure pulsations, the side branch resonators are installed between the hydraulic pumps and hoses. Because the side branch resonator has a good performance at the narrow frequency range, its length need to be accurately tuned to 383Hz as the excitation frequency of the pressure pulsations. The noise levels at cabin and outside according to the length of resonator and the pump installed resonator are investigated.

The noise difference between the basic and modified model at outside and cabin are shown in Figure 2 and Figure 3, respectively. The resonators of 96cm length, which is tuned based on the theory and our experience, are the most effective. In addition, the outside noise level of 400Hz octave band is reduced in the experimental condition installed the resonators of 96cm length at pump 1 and pump 2, and it is effective on the cabin noise reduction of 400Hz octave band and high frequency range to apply the resonators of 96cm length to pump 1 and pump 3. The locations of hydraulic hoses and valves connected with each pump have different effects on the noise levels at cabin and outside according to the pump applied the noise control device.

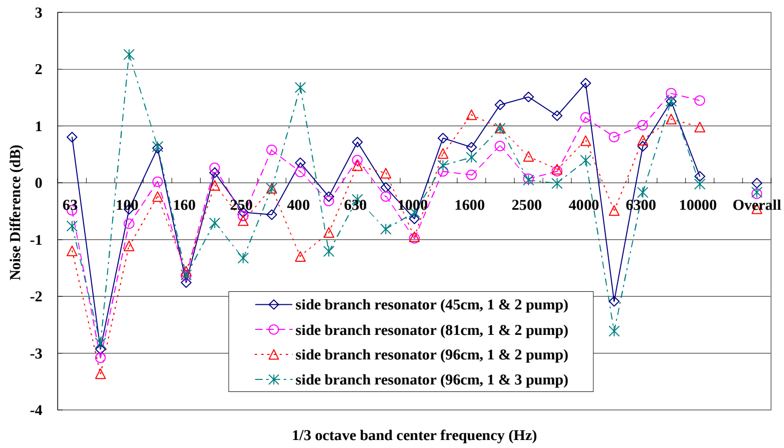

Figure 2 The noise difference at outside (installation of the side branch resonator)

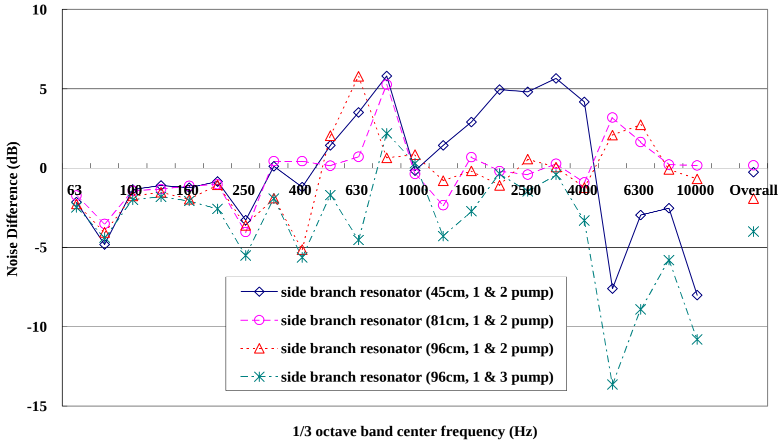

Figure 3 The noise difference at cabin (installation of the side branch resonator)

Applying the reflection silencer to 1st model

In the case of hydraulic silencer, the noise analysis using BEM software is performed to design the silencer with a good performance. The calculated transmission loss for various silencer models is shown in Figure 4. As a result, the simple reflection silencer has the advantages of performance and manufacture.

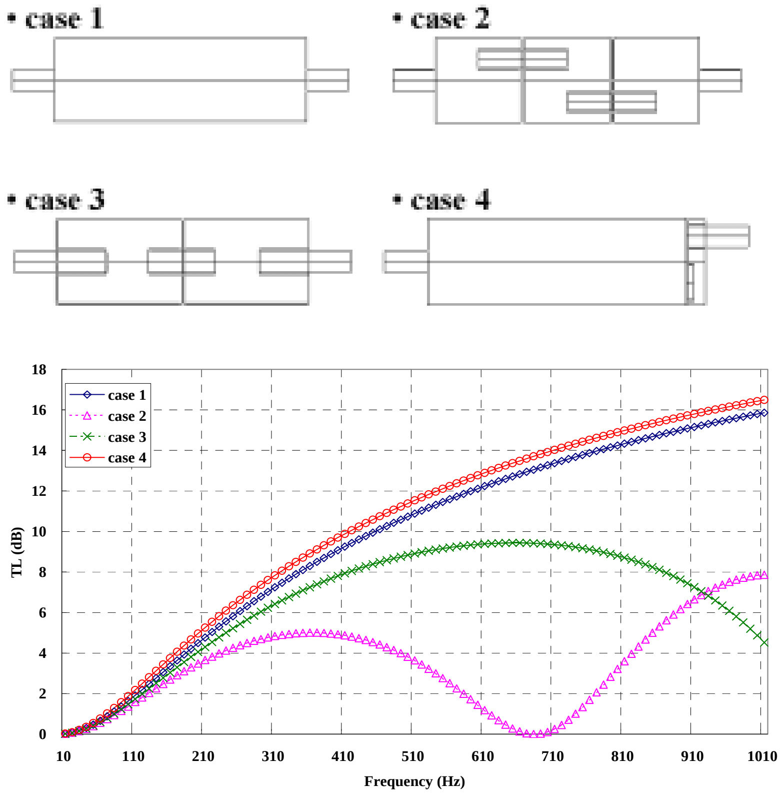

Figure 4 The calculated transmission loss for various silencer models

To investigate the noise levels at cabin and outside according to the diameter of reflection silencer and the pump installed silencer, the reflection silencers with diameter of 29mm and 34mm are applied to each pump. The noise difference between the basic and modified model at outside and cabin are shown in Figure 5 and Figure 6, respectively. As a result, the silencer of 34mm diameter is about 2~5dB more effective on the cabin and outside noise levels of 400Hz octave band, and in the same manner with resonator, it is more effective on the hydraulic noise reduction of outside to install the silencer at pump 2 than other pumps. Also, the reflection silencer is good at the hydraulic noise reduction of 800Hz octave band.

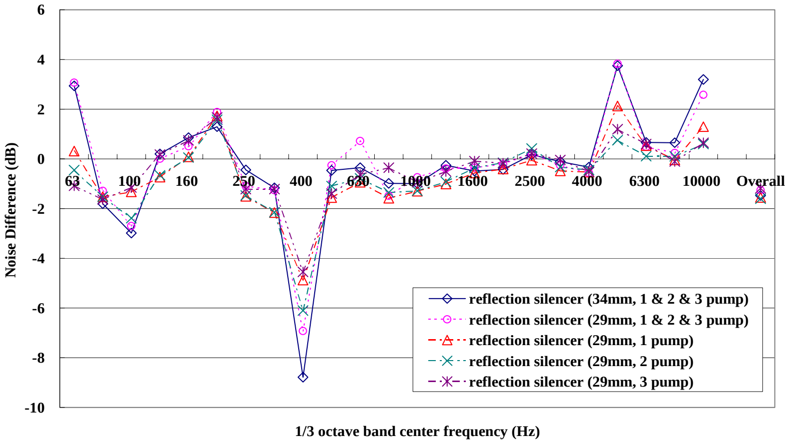

Figure 5 The noise difference at outside (installation of the reflection silencer)

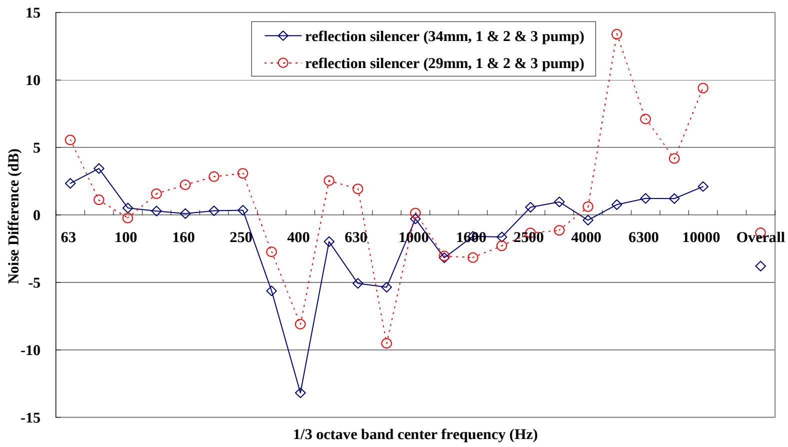

Figure 6 The noise difference at cabin (installation of the reflection silencer)

Applying the reflection silencer to 2nd model

In the case of the 2nd model, the hydraulic noise frequencies are 184Hz and its harmonics as shown in Figure 7. And it represents that the hydraulic noise levels of cabin due to the installation of reflection silencer are reduced, and especially, the 2nd order hydraulic noise level is lowered about 14dB.

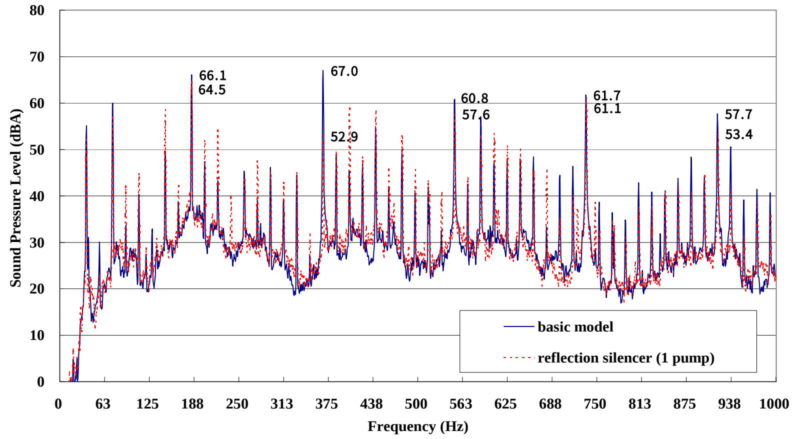

Figure 7 The noise levels at cabin (installation of the reflection silencer)

REDUCING STRUCTURE-BORNE NOISE

The vibration of adjacent structures induced by the fluid-borne and structure-borne noise of hydraulic system can be reduced through the isolation of connected structures from hydraulic components. However, the structure-borne noise is transmitted to the outer frame of excavator through the vibration of structures connected and contacted with hydraulic system, and it is transmitted into the air-borne noise of outside. Therefore, to lower the structure-borne noise of adjacent structures, the damping materials and dynamic absorbers are applied to the real hydraulic excavator.

Applying the damping material and dynamic absorber to 1st model

The damping materials and dynamic absorbers are applied to the outer frame of under the cabin where the structure-borne noise is relatively high. The damping material is made of rubber and are self-adhesive with 3~4mm thickness. And the dynamic absorber is designed and tuned to absorb the vibration of 383Hz induced by hydraulic system.

The noise difference between the basic and modified model at outside is expressed in Figure 8 and the hydraulic noise levels of 400Hz octave band is reduced about 3~4dB and the overall noise levels are lowered about 1dB due to the damping materials and dynamic absorbers. In addition, these countermeasures are good at the outside noise reduction of the high frequency range due to the decrease of vibration at the broadband including the hydraulic noise.

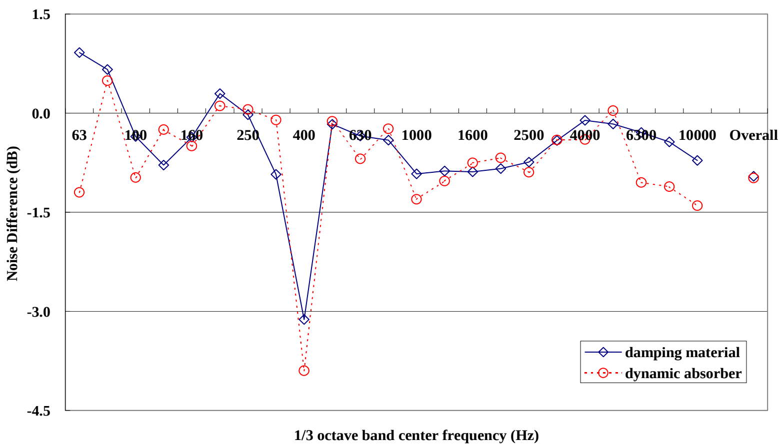

Figure 8 The noise difference at outside (application of the damping materials and dynamic absorbers)

CONCLUSION

In this study, the performances of the hydraulic silencer and side branch resonator as noise control devices have been analyzed and tested on real hydraulic excavator to reduce the propagation of fluid-borne noise. In addition, the damping materials and dynamic absorbers have been applied to lower the structure-borne noise of adjacent structures.

The side branch resonator and reflection silencer have a good performance at the excitation frequencies of the pressure pulsations, and the reflection silencer is more effective and simple. Also, the damping materials and dynamic absorbers are good at the outside noise reduction of the broadband including the hydraulic noise. As a result, the sufficient noise reductions at cabin and outside of the excavator have been obtained by the application of the countermeasures for the hydraulic noise.

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