Study on Noise Reduction of AV Projector

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Abstract

To reduce acoustic noise level of an AV projector, primary noise sources of AV projector were analyzed. Based on the analyzed result, methods to control each source are presented and tried. Structure-borne noise can be controlled by anti vibration design of mounting system, and air-borne noise by reducing flow resisitvity.

1. Introduction

Noise and vibration of home electrical devices (domestic appliance) are essential characteristics for customers. Low noise and vibration are always benefits, especially if the device operates in a quiet place. Recently, as the projector market is rapidly expanding from preexisting data projector to AV projector for home theater, noise level of a projector has become one of the critical issues. Projector noise may disturb users when they watch movies at low loudness.

Since the primary sources of noise and vibration in a projector are cooling fans and color wheel, design for isolating vibration of these items should be studied at the design stage. In addition, not only sound pressure level of noise, but also quality of sound should be considered.

For the reduction of acoustic noise of an AV projector, structural vibration and acoustic characteristics of an AV projector were studied. The acoustic noise of an AV projector could be categorized into three parts; the directly radiated noise from a rotating body, the flow-induced noise due to turbulence or vortex generated by obstacles in the projector, and the structure borne noise radiated from vibrating elements. The primary sources of these kinds of noise and vibration are cooling fans and the color wheel (in case of DLP projector). Since the structure of the optical module and the case of a projector can be excited by the excessive vibration of fans or color wheel, the vibration isolation design should be considered. In this study, anti vibration mountings for fans and color wheel are applied for controlling structure borne noise. For airborne noise, some experiments and analyses are executed.

2. Analysis of noise sources

Sound intensity for sound power determination was measured over the five surfaces which are parallel to projector walls and which form rectangular parallelepiped (fig. 1). Distance from projector to measurement surface is 15cm. Intensity measurements were carried out using scanning technique (ISO 9614-2)

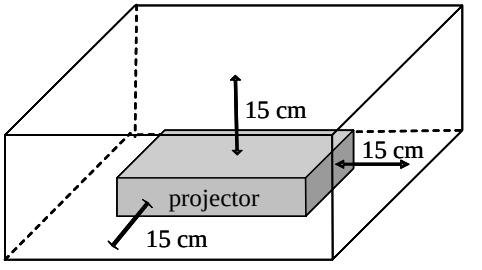

Fig. 1. Surfaces where sound intensity was measured.

It can be seen from fig. 2 that frequencies 315–2000 Hz provide the main contribution in total sound power in dB(A). It means that noise reduction in this frequency range is most effective for decreasing of dB(A) values which are usually used as integrated index of noisiness. Further special attention will be paid to this frequency range.

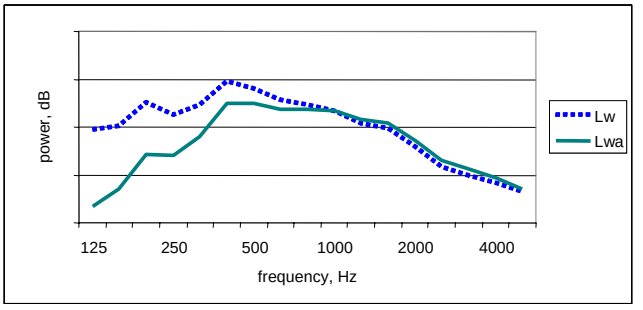

Fig. 2. Sound power of projector (L_w) and the same value with A-correction (L_{wA}).

Four fans operate inside a projector at nominal operating mode. Fans characteristics are presented in table 1. To evaluate contribution of each fan into total sound power these fans are run separately. Sound power of projector, when only one of fans is operating, is measured using intensity technique.

TABLE 1. Characteristics of fans.

Fan	Type
Exhaust fan	axial
Power fan	axial
DMD fan	axial
Lamp fan	centrifugal

The results are presented in fig. 3. It can be seen that contribution of each fan into total sound power is approximately the same. At some frequencies, noise from some fans dominates. But dominance is not essential and each fan contribution should be decreased to decrease noise from projector.

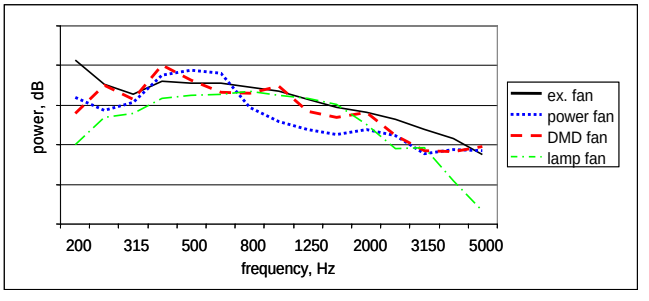

Fig. 3. Sound power of projector when fans operate separately.

In Fig. 6, Sound power of projector calculated as a sum of sound powers of separate fans and measured values at nominal operating mode are presented. Shapes of spectra are conformed. Although they do not coincide, it may mean that fans are the main noise sources. I.e. other projector components do not influence on noise significantly.

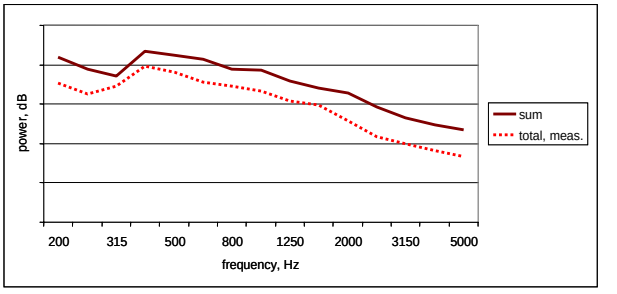

Fig. 4. Sound power of projector calculated as a sum of sound powers of separate fans and measured values at nominal operating mode.

Projector components not only radiate noise but generate some vibration as well. Vibration propagates over the projector structure, some part of vibratory energy radiates into outer media. This component of radiated noise is called structure borne noise.

To study influence of housing vibration on radiated noise, vibration in housing is simulated using shaker. Walls vibration is measured on projector housing in 17 points (top wall – 5 points, bottom wall – 4 points, side walls – 2 points on each wall).

Transfer functions from walls vibration to sound radiation – the difference between mean vibration and radiated sound power – are presented in fig. 5.

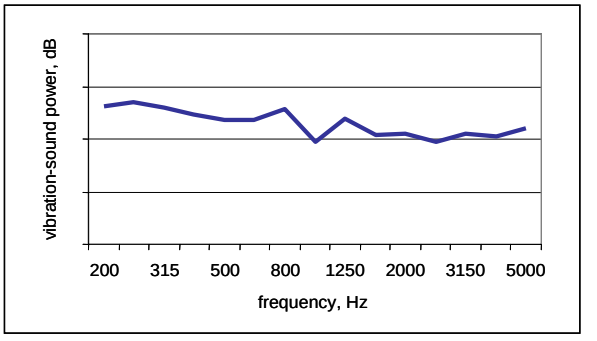

Fig. 5. Transfer function from walls vibration to sound radiation.

Adding transfer function to vibration of projector walls at nominal operating mode, one obtains sound power of projector caused by vibration at nominal operating mode, which is presented in fig. 6 along with sound power at nominal operating mode. It can be seen that vibration may determine sound radiation

at frequencies 400–800 Hz. The cause of vibration may be mechanical vibration of projector components or turbulent flows inside projector.

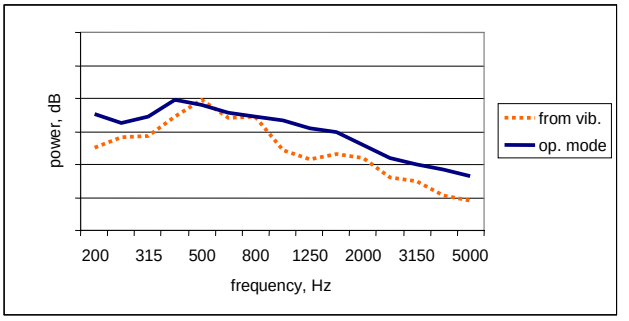

Fig. 6. Total sound power of projector on nominal operating mode and sound power caused by vibration, calculated on the basis of experiments, which consist in vibration simulation by shaker.

As you can see in previous result, most significant sources of projector noise are fans. Causes of noise due to fans are vibration and flow. In order to control each cause, different method for each cause should be applied.

3. Structure borne noise of fan

The most common way to reduce vibration transmission from source is applying rubber bushing to mounting system. Sound pressure level of projector, when only one of axial fans is operate, is measured. Table 2 shows the result of averaging measured sound pressure level of the projector from four directions; front, rear, left, right. The difference between with and without rubber bushing is shown very clearly.

TABLE 2. Averaged sound pressure level of projector when rubber bushing is inserted and not.

BRACKET	Rubber Bushing	SPL(dBA)
SECC	X	28.4
SECC	O	25.1

For lamp fan (centrifugal), anti-vibration panel was used to make mounting bracket. Anti-vibration panel is multi-layered panel which is designed to isolate vibration. The comparison result – bracket made from steel VS anti-vibration panel – is presented in fig. 7. As using anti-vibration panel, overall noise level decreased by 1dB. Decrease at frequency range of 1~2 kHz - resonance frequency range of light barrel to which the lamp fan is attached - is relatively big, which may mean this mounting bracket insulates vibration effectively.

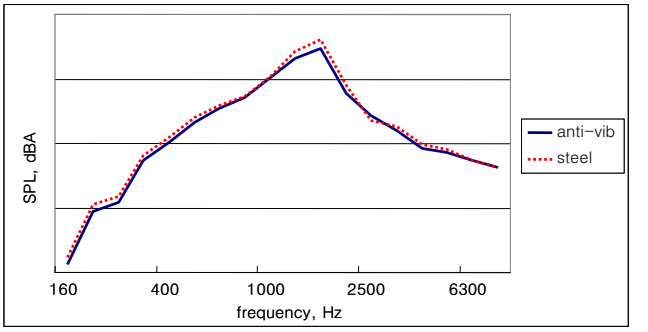

Fig. 7. Sound pressure level of lamp fan with steel bracket and with anti-vibration bracket.

4. Air borne noise of fan

Some experiments which confirm influence of flow irregularity on fan noise have been done. Exhaust fan and air diffuser (as obstacle), which is regularly placed inside projector at exhaust fan input, are used for experiments. Sound intensity on fan axis is measured when fan operates in semi-infinite space without and with obstacle for flow (fig. 8). Measurements were done for different combinations of mutual position of fan, obstacle and measuring point.

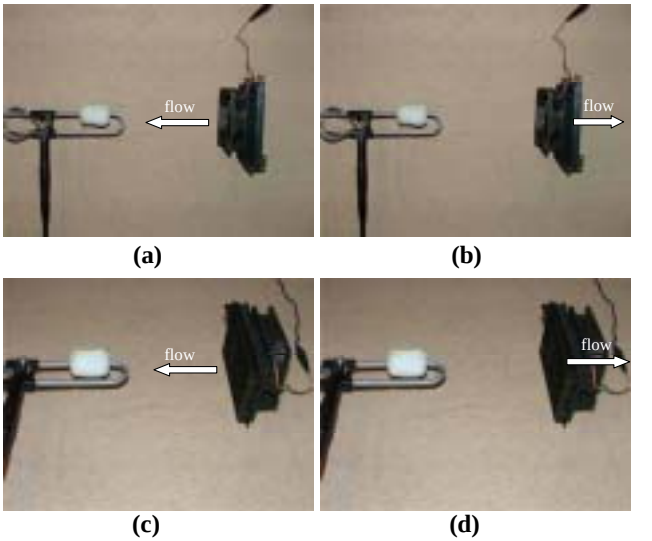

Fig. 8. Fan and obstacle mutual position.

The results of measurements are presented in fig. 9. It can be seen that obstacle significantly increases sound radiation from this fan in a wide frequency range. Noise increasing is more significant when obstacle is placed at fan input. The value of increasing is up to 7 dB. Similar processes occur when fan is placed inside projector.

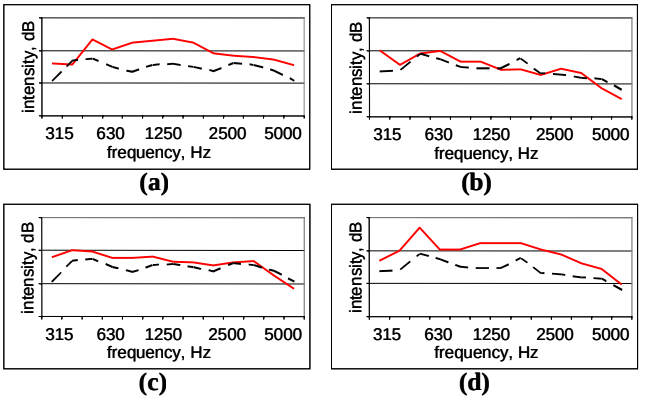

Fig. 9. Sound intensity with (solid red) and without (dashed black) obstacle near fan; a, b, c, d correspond to denotations in fig. 8.

4. Color wheel noise

Cooling fans are most responsible for the noise in projector. In case of DLP projector, however, the color wheel is also one of major noise sources. Although total sound power of the color wheel may not be a big portion, special care about high frequency noise is required because it usually rotates at higher speed than fans; usually 7200~14400 rpm.

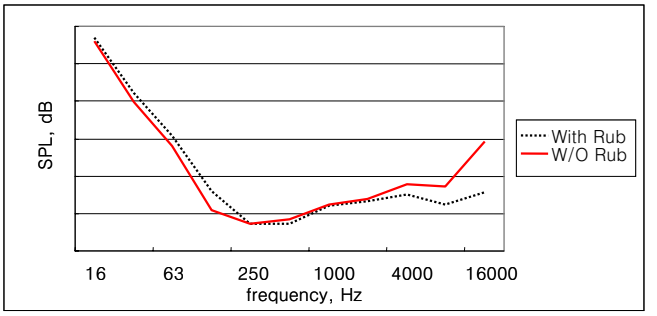

Fig. 10. Sound pressure level of projector when color wheel operates separately.

Rubber bushing is used to insulate color wheel vibration as well as fan. Sound pressure level of projector, when only color wheel is operating, is measured. The result is presented in Fig. 10. When rubber bushing is used, noise level decrease at higher frequencies is remarkable.

5. Summary

In order to reduce noise level of AV projector, some experiments and analysis were conducted. At first, major noise sources were defined and analyzed. Structure borne noise of fans and color wheel was decreased by applying proper vibration isolation materials. For air borne noise, characteristics of flow induced noise according to obstacle arrangement was studied.

5. References

1. Leo L. Beranek and Istvan L. Ver, *Noise and Vibration Control Engineering*, John Wiley & Sons, NY (1992).
2. E. H. Stupp and M. S. Brennesholtz, *Projection Displays*, John Wiley & Sons, NY (1999)
3. Dae Kyong Park, Dong Seob Jang and Chul Min Park, *KSNVE*, **14[9],** pp.861~867 (2004).