EFFECT OF NEXT GENERATION COMPUTER COOLING FAN SPEED ON ACOUSTIC NOISE EMISSIONS

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1. INTRODUCTION

Graphic Processor Units (GPUs) on the latest models of computer graphic cards generate significant amounts of heat. In fact, the required dissipation rate is so large that cooling fans mounted on heat-sinks must be used to maintain satisfactory temperatures. Where space limitations allow and heat transfer requirements dictate, blower type fans are implemented due to their ability to deliver higher flow rates compared to more traditional axial flow fans. The operation of these blower fans, particularly at high speeds, results in the generation of noise which is experienced by the user. Both computer manufacturers and consumers alike have deemed this noise to be excessive and annoying.

The purpose of this study was to investigate the realized acoustic performance of a blower style fan-sink mounted on an advanced graphics port (AGP) card. The goal of this investigation was to determine what thermal benefits of higher flow rate are realized by the blower fan at the expense of increased noise emissions.

2. METHOD

To determine the relationship between fan speed and acoustic performance, the RPM on the fan was adjusted to operate at five different speeds by varying the input voltage to the fan. All acoustic testing was performed with the fan-sink mounted on a video graphic card in a stand-alone arrangement where the video card was not placed inside a computer chassis.

The sound power levels of the fan-sinks were calculated from sound pressure level measurements collected in a hemi-anechoic room. The testing was carried out in compliance with the ECMA-74, "Measurement of Airborne Noise Emitted by Information Technology and Telecommunication Equipment". Sound power levels were calculated from the sound pressure measurements as detailed in ISO 3745, "Determination of Sound Power Levels of Noise Sources". This method involved the acquisition of ten sound pressure level measurements around the noise source in a hemi-spherical pattern specified in ISO 3745. Adjustments were also made to account for the surface area of the test sphere as well as atmospheric conditions and ground reflections.

Sound pressure level results were also measured in the hemi-anechoic room using a binaural head manikin. The rationale for using a binaural head is to acquire data that best represents what would be perceived by an actual person for psychoacoustic analysis. The installation and operating conditions of the sound pressure level measurements were conducted in compliance with both ECMA-74 and ISO 7779, "Measurement of Airborne Noise Emitted by Information Technology and Telecommunication Equipment".

As part of this investigation, psychoacoustic metrics were used as part of the evaluation process. Psychoacoustics is a measure of the perception of how good or bad the character of a noise source is, as perceived by the human ear. For this study loudness and prominent tone (PR) were the evaluated psychoacoustic metrics. Loudness is a measure of the human perception of how loud a source is perceived to be as opposed to simply reporting a sound pressure level. Prominent tone provides an objective measure on the prominence of a tonal component in a sound. A tone is said to be prominent if its PR exceeds 7 dB and is usually reported with the frequency at which the prominent tone is located.

3. RESULTS

Figures 1 and 2 illustrate the results of both sound pressure level and sound power level vs. fan RPM measurements, respectively for the blower fan-sink. A linear increase in levels is seen for both with increases in fan speed. Figure 3 illustrates the loudness results versus fan speed for the blower heat-sink. Unlike the sound pressure and power level graphs, the loudness curve is not linear. Loudness is very frequency dependant. Its calculation is rather complicated and includes other characteristics such as temporal masking effects. As such, no simplistic relationship exists between the sound level metrics and loudness. Loudness, however is still a good indication of perceived noise emission and is therefore still expected to increase exponentially since it is not presented by logarithmic values. This exponential trend is evident in Figure 3.

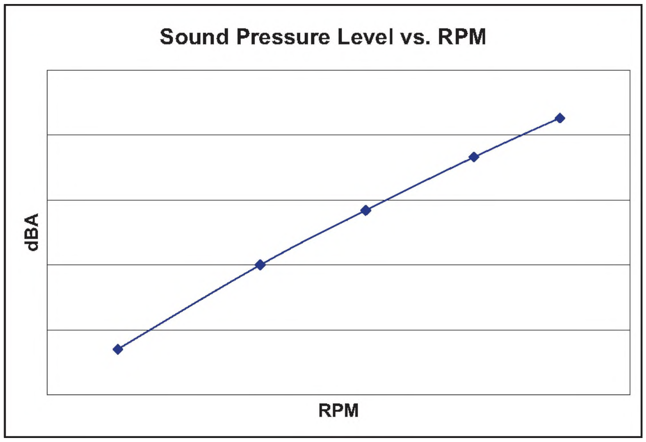

Figure 1: Sound Pressure Level vs. RPM for Blower Fan-Sink

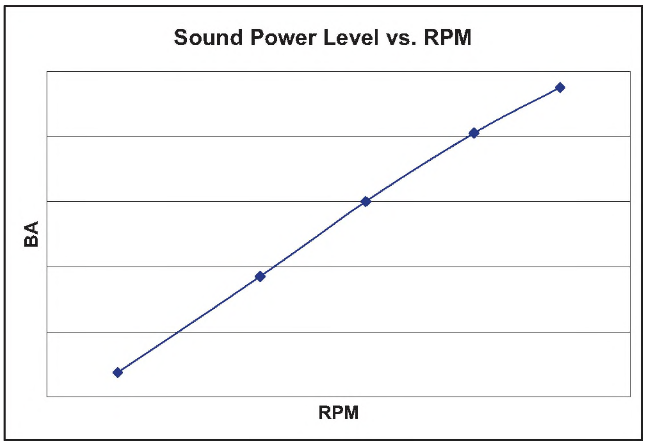

Figure 2: Sound Power Level vs. RPM for Blower Fan-Sink

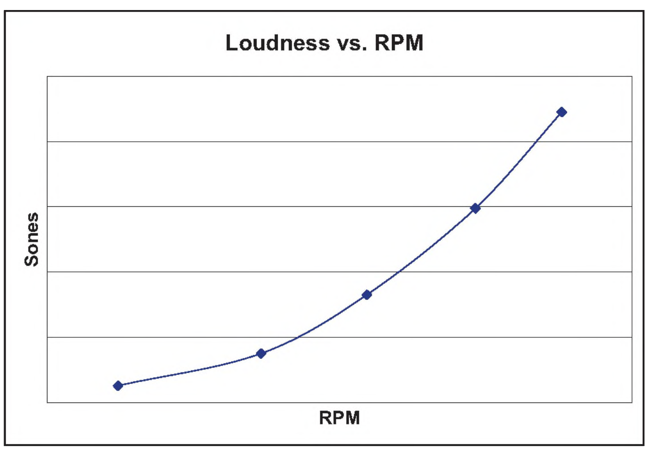

Figure 3: Loudness vs. RPM for Blower Fan-Sink

Table 1 illustrates the measured prominent tones and the respective frequencies at which they are found. Inspection of the results suggests that no direct relationship between fan speed and prominent tone exists. Indirectly this is false. Aside from the case of a faulty operating fan, a prominent tone is often the result of spatially fixed irregularities that can produce a wake at either the inlet or outlet. These dynamic changes can cause prominent tones at the fan blade passage frequency, which is a multiple of the fan speed, number of fan blades and any obstructions such as sink fins. The amplitude of these resonances do not increase with fan RPM but instead increase and decrease like an incoming wave and will occur at frequencies that are multiples of each other.

Table 1: Prominent Tone Result for Blower Fan-Sink

Voltage	RPM %	Prominent Tone (dB)
6	48	8.4 @ 669 Hz
8	63	8.7 @ 594 Hz
10	77	9.6 @ 581 Hz
12	90	6.7 @ 581 Hz
14	100	4.8 @ 606 Hz

As part of a previous investigation, it was reported that the thermal performance of this fan-sink improved with an increase in fan RPM. However, this thermal performance improved at a lesser rate when the RPM was increased further. This, along with the acoustic results presented here, suggest that a diminished rate of thermal improvement with increased fan speeds are accompanied by negative increases in unwanted noise emissions. This was demonstrated using the metrics of sound pressure and power levels as well as loudness.

4. SUMMARY AND CONCLUSIONS

Acoustic experiments were conducted on a next generation blower type fan-sinks to investigate the benefits of higher fan flow rate versus the effect on noise level. A previous study showed that thermal performance of the fan-sink improved with an increase in fan RPM, however, the performance improved at a lesser rate when the RPM was increased further. Noise on the other hand increased steadily. No direct correlation between an increase in fan speed and prominent tone was realized.

This study showed that while increasing fan speed did increase thermal performance, it also had a negative effect on noise emissions. Care must be taken in optimizing fan speed so as to gain the best thermal performance without producing detrimental noise levels.