THE EFFECT OF VARYING HEAT SINK FIN DISTANCES FROM COOLING FAN BLADE TIP ON NOISE EMISSIONS

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INTRODUCTION

The challenge to deliver performance improvements in computer graphic cards has surpassed the ability of finned, passive, cooling devices to dissipate the heat generated by next generation graphics processing units (GPU). The dissipation rates required by these latest GPU designs can only be delivered by more complicated thermal management systems which often require forced air cooling of finned heat sinks. The concurrent challenge to the industry is to provide this cooling while minimizing the noise generated by these cooling fans. One of the fundamental mechanisms for the generation of fan noise is the dynamic force fluctuations on the fan blade and how these fluctuations interact with fixed irregularities such as adjacent cooling fins. This study investigates the effect on the acoustic emissions resulting from the variation of the distance between the fan blade tips and the heat sink fins.

COOLING FAN NOISE

The generation of cooling fan noise is usually attributed to two fundamental source mechanisms. Both of these are sources of dynamic force variations between the surface of the fan blade and the immediate surrounding air.

The first of these is random generated noise produced at the fan inlet. If the inlet flow is turbulent, a force results which is dependant on the influence of the lifting force to the angle of attack. Acoustic models which predict the generated sound power of this force can be readily found in aeroacoustic literature. The resulting amplitude of this random noise generation is directly dependant on the level of inlet turbulence. As such, the inlet path must be kept as unobstructed as possible to minimize the creation of any turbulence.

The second source of noise generation is caused by spatially fixed irregularities which can produce a wake in either the inlet or outlet flow. In the case of computer cooling solutions, these irregularities can be the result of either the presence of heat sink fins or an improperly designed shroud. The resulting dynamic forces can contribute to strong tones which are usually found at the blade passage frequency.

To lessen the impact of these mechanisms of noise generation, one can either modify the blades of the fan or lessen the impact of the irregularities on the flow. For this study, the affect of the distance between the fan blade tips and the heat sink fins has on the acoustic emissions is experimentally investigated.

NOISE MEASUREMENTS

For this investigation, the emitted sound pressure level (SPL) at a distance of 0.5 metres as well as the radiated sound power level was determined. While A-weighted SPL is the traditional analytical approach and serves well to quantify the amplitude of acoustic emissions, it offers no insight to the perceived quality of the sound produced by the graphic card cooling fans. Given this, the acoustic product evaluation of computer graphic card cooling noise should include sound quality or psychoacoustic analysis. Therefore, in order to truly determine the full acoustic impact that an active cooling solution will have on the end user, the measurement of the applicable psychoacoustic metrics is warranted.

For this investigation, measurements of loudness will be presented. While somewhat similar to the A-weighting scale discussed above, loudness is a more detailed representation of how loud a source is perceived. It also includes compensation for the effect of temporal processing and audiological masking effects of sounds across the frequency range. Also determined in this study is prominent tone (PR). This psychoacoustic metric gives an objective measure of the prominence of a tonal component of a measured sound. The prominent tone is defined as the ratio of the power of the critical (frequency) band centred on the tone under investigation to the mean power of the two adjacent critical bands. For this investigation, only the presence of prominence will be indicated.

In order to investigate the affect of varying distance between the 53 mm diameter fan and the sink fins, a movable fin design was devised. This fin module, which was radiused to the contour of the impeller, was designed to be positioned at six different distances from the tip of the fan blades. The distances used were 1mm, 4mm, 7mm, 10mm, 13mm and 16mm. The fan was operated at each of the six distances at three different speeds.

RESULTS AND DISCUSSION

Figure 1 illustrates the measured sound pressure level results of each fan-fin distance for each of the three measured speeds. An obvious pattern exists for each of the speeds. The sound pressure level is greatest for the 1mm and 4mm spacing between the fan tip and cooling fin. However, after the spacing is increased to 7 mm, the sound pressure level exhibits a rapid decline where it remains somewhat constant for subsequent spacings of 7mm, 10mm and 13mm for this fan. For the 16mm distance between the fan and fin another rapid decline in sound pressure level is realized. Inspection of Figures 2 and 3 for sound power level and Loudness respectively show very similar trends in the measured data.

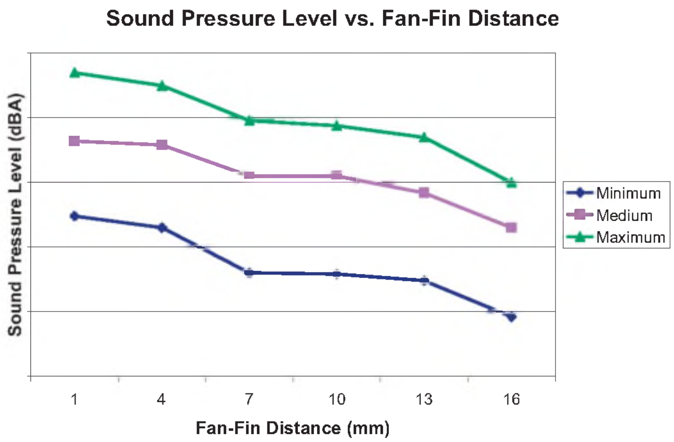

Figure 1: Graph of Measured Sound Pressure Level versus Distance from Fan tip to Cooling Fin for 3 Fan Speeds

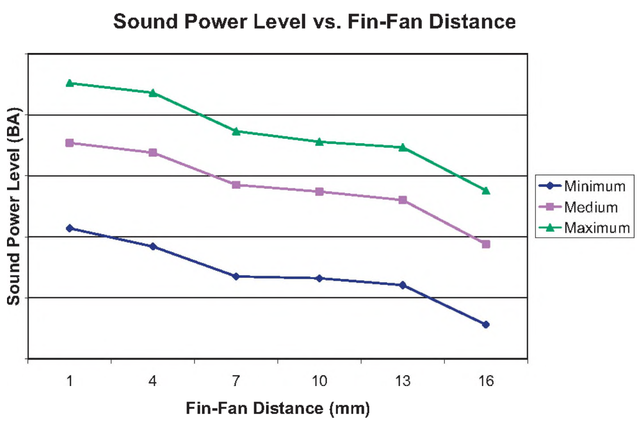

Figure 2: Graph of Calculated Sound Power Level versus Distance from Fan tip to Cooling Fin for 3 Fan Speeds

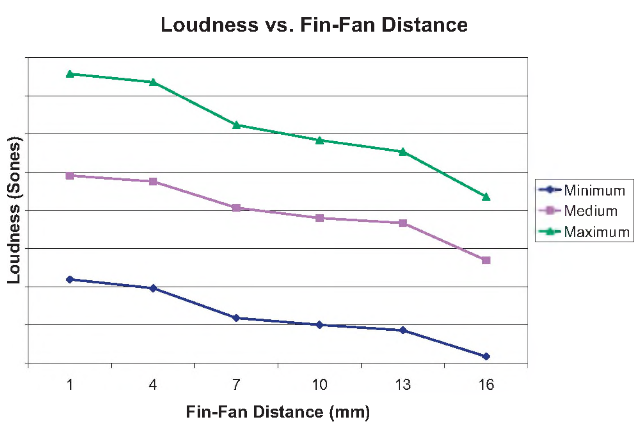

Figure 3: Graph of Calculated Loudness versus Distance from Fan tip to Cooling Fin for 3 Fan Speeds

For very close clearance spacing between the blade tip and cooling fin, it appears that a prominent mechanism of noise generation is present. Due to flow straightening affects of the long fins, it is safe to assume that the flow at the immediate exit would not be highly turbulent. The noise generation would then be surmised to be the result of the presence of the spatially fixed irregularities in the very close proximity of the blade tips. This is reinforced by the presence of prominent tones at the two closest distances as is shown in Table 1. It should also be noted that the type of noise generation demonstrated here can at times also be controlled by other means including redesign of the fan blade curvature or cross sectional profile. The latter of these two is more effective for larger diameter fans.

Table 1: Presence of Prominent Tone (Yes/No)

Distance (mm)	Minimum	Medium	Maximum
1	Yes	Yes	Yes
4	Yes	Yes	Yes
7	No	Yes	No
10	No	Yes	Yes
13	No	No	No
16	No	No	No

For the distances of 7 mm, 10 mm and 13 mm, an obvious reduction in noise emission is observed. Further, it is seen that the changes in noise level caused by the change in spacing are not very different from each other. It is suggested that the noise is created by a combination of both noise generation mechanisms. Inspection of Table 1 demonstrates a continued presence of prominent tones at the 7 mm and 10 mm distances. Therefore, the interaction of the cooling fins with the dynamic forces at the blade tips is still present. It should also be noted that, as the distance is increased, the flow straightening affect of the cooling fins is lessened. In other words, there is an increase in noise generation due to an increasing level of turbulence. Once the cooling fins have been located at a distance of 15 mm from the fan, another drop in acoustic emissions is realized.

SUMMARY AND CONCLUSIONS

Through the use of acoustic measurement and analysis techniques, it has been demonstrated that the generation and presence of acoustic emissions is the result of the two mechanisms of noise generation discussed. From the presented results, it has been shown that a fine balancing act is necessary to minimize the noise emissions caused by these two mechanisms. While it is obvious that a decrease in sound level is realized with increasing distance between the cooling fins and fan blades, a definitive decision of optimum distance can not be made in the absence of consideration of the required thermal performance of the heat removal system. Instead, careful design of the fan rotor and shroud used for flow directionality shroud be given great design importance.