USE OF PSYCHOACOUSTIC METRICS FOR THE ANALYSIS OF NEXT GENERATION COMPUTER COOLING FAN NOISE

Colin Novak[1], Helen Ule[1], Robert Gaspar[1], and Robert Wiley[2]
[1]Dept. of Mechanical Automotive and Materials Engineering, University of Windsor
401 Sunset Ave.; Windsor, Ontario; Canada; N9B 3P4
[2]ADDA Corporation – North American Thermal Division, 910 Campisi Way, Campbell, California; USA; 95008

1. INTRODUCTION

The competitive drive for performance improvements in computer processing abilities necessitate the inclusion of finned active cooling devices to dissipate the heat generated by the computer processing unit (CPU). In more recent years, the heat flux generated has increased with further performance improvements. The result being that much more complex forced air cooling solutions are required. One aspect that now challenges the industry is to provide this cooling while minimizing noise generation. A significant feature to this problem is missed if one only considers the problem to a one-dimensional sound level issue. From a consumer's perspective, the perceived quality of the noise emitted takes precedence over what traditional acoustical analysis techniques of this fan noise may imply. Here, sound quality metrics may be a more applicable analysis tool as it makes possible the quantification of these qualitative human impressions.

The present study investigates the validity of using several psychoacoustic metrics for acoustic analysis of two different cooling solutions. A discussion and comparison of measured results using traditional analysis techniques is also included. A discussion of the applicability of the various metrics along with justifications is presented.

2. MEASUREING COMPUTER FAN NOISE

The procedures, installation and operating conditions of acoustic testing for computer noise sources are regulated by several standards. These include ECMA-74, "Measurement of Airborne Noise Emitted by Information Technology and Telecommunication Equipment" and ISO 7779, "Measurement of Airborne Noise Emitted by Information Technology and Telecommunication Equipment". The method used to measure and calculate sound power level using free field sound pressure measurements is detailed in ISO 3745, "Determination of Sound Power Levels of Noise Sources".

Traditional analytical approaches serve well to quantify the amplitude of acoustic emissions, but they offer no suggestion as to the quality of the sound produced by the cooling fans. Sound quality can significantly affect the acceptability of a product to the consumer. Given this, acoustic product evaluation of next generation computer cooling solutions must also include a sound quality or psychoacoustic analysis in order to truly determine the full acoustic impact that an active cooling solution will have on the end user.

The science of psychoacoustics involves the quantitative evaluation of these subjective sensations using sound quality metrics. Application of sound quality metrics allow for the visualization of the complicated relationship that exists between the physical and perceptual acoustic quantities. For this investigation, sound quality metrics including loudness, sharpness, roughness, prominent tone and articulation index were used to evaluate cooling fan noise of three different cooling fan-sink designs. The designs were chosen on the basis of the variety of acoustic characteristics they exhibited.

3. RESULTS

Figures 1 and 2 illustrate the results of the sound pressure level and sound power level versus fan RPM measurements respectively for each of the three fan designs. What is most relevant for this study is the realized amplitude range of acoustic emissions.

Inspection of both the sound pressure level and sound power level results illustrate a linear increase in acoustic emission levels. Observable from these figures is the fact that the smaller fan (design 1) spans the largest speed range and can run at the highest RPM when compared to a blower type fan (design 3) option; yet, they both generate approximately the same range of acoustic noise. The second design had the smallest range of both RPM and acoustic noise. A conclusion that one might draw from both Figures 1 and 2 is that fan RPM range has a greater impact on predicting noise emissions rather than the simple magnitude of the fan speed.

Figure 3 illustrates the loudness results versus fan speed for the three designs. The calculation of loudness involves an algorithm which is frequency dependant and includes other characteristics such as temporal masking effects. This dimension of human perception adds to the meaningfulness of using this metric.

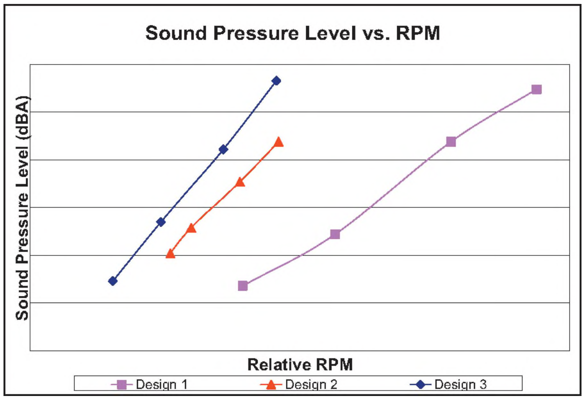

Figure 1: Sound Pressure Level vs. RPM for the Three Fan-Sink Design Options

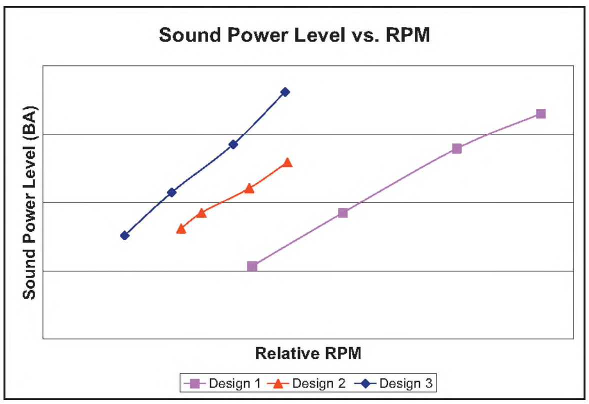

Figure 2: Sound Power Level vs. RPM for the Three Fan-Sink Design Options

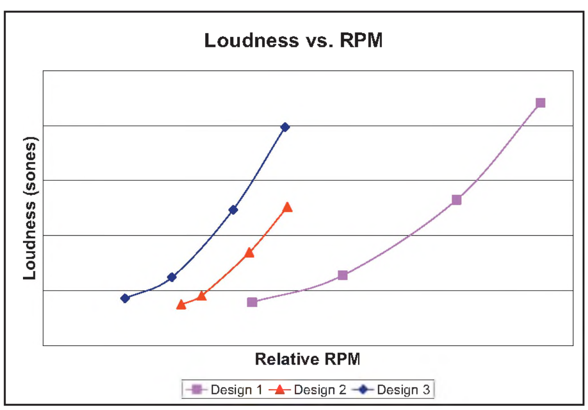

Figure 3: Loudness vs. RPM for the Three Fan-Sink Design Options

Table 1 illustrates the results of the remaining psychoacoustic metrics for each of the three fan designs at each of the operating speeds tested. Included are sharpness, roughness, prominent tone and articulation index.

Table 1: Psychoacoustic Results

Design 1				
RPM %	**40 %**	**60 %**	**80 %**	**100 %**
Sharpness	1.99	2.25	2.95	3.45
Roughness	3.70	3.85	4.11	4.02
Prominent Tone (dB)	6.9 @ 465 Hz	7.9 @ 727 Hz	6.9@ 1288 1545 Hz	10.3 @ 845 Hz
Articulation Index (%)	99.05	98.05	89.35	80.13
Design 2				
RPM %	**44 %**	**62 %**	**84 %**	**100 %**
Sharpness	1.56	1.86	2.69	3.72
Roughness	4.12	5.15	5.56	6.32
Prominent Tone (dB)	6.1 @ 656 Hz	7.3 @ 1845 Hz	4.5 @ 2088 2045 Hz	5.1 @ 2250 726 Hz
Articulation Index (%)	99.45	99.45	99.4	95.32
Design 3				
RPM %	**35 %**	**53%**	**80 %**	**100 %**
Sharpness	1.1	1.2	1.61	1.75
Roughness	3.21	3.33	4.45	4.25
Prominent Tone (dB)	5.3 @ 669 Hz	10.8 @ 724 Hz	7.1 @ 419 2425 Hz	8.7 @ 581 2236 Hz
Articulation Index (%)	99.10	98.95	98.95	90.45

Inspection of the remaining psychoacoustic metrics provides valuable information. Inspection of sharpness, which is an indicator of high frequency annoyance, increases consistently with fan speed. This is not unexpected given that as the fan speed is increased, so is the amount of air noise and turbulence. A similar argument holds for the modulation metric of roughness perhaps indicating some imbalance. Such is not true for the prominent tone results for which high levels above 8 dB are more likely due to the fan blade passage frequency, which is a multiple of the fan speed, number of fan blades and any obstructions such as sink fins. For circumstances where a noise source is located in an area where the comprehension of speech is important, the measurement of articulation index is a very useful metric. In this case, all reported values are acceptable.

4. CONCLUSIONS

The focus of this investigation was to investigate the validity of using several different psychoacoustic metrics for the analysis of fan cooling computer noise. Traditional noise analysis techniques were also conducted.

The results of most of the metrics were correlated with the operational fan speeds and all of the metrics demonstrated results useful for qualitative product analysis. It can further be concluded that while traditional noise analysis techniques provide useful information, they do not represent the entire impact that computer cooling fan-sink noise can have on the human ear.