COMPARITIVE STUDY OF NOISE AND VIBRATION MEASUREMENTS OF COMPUTER COOLING FANS

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INTRODUCTION

Due to consumer demands in the computer industry, video processor chips have become more powerful with a resulting requirement to dissipate ever increasing amounts of heat. As such, the performance requirements of cooling fans have been increasingly taxed to deliver higher flow rates. To accomplish this, large fans of various designs are used at relatively high rotational speeds. This, however, often results in structural resonance due to dynamic imbalances of the fan rotor. With larger fans are larger fan housings which often have higher acoustic radiation efficiencies resulting in a 'speaker effect' which can amplify the fan vibration into audible noise. This study investigates the relationship between measured vibration levels of several cooling fan heat sink designs to experimentally determine acoustic emission levels. Specifically, an attempt to correlate the realized acceleration levels to both sound power and sound pressure levels was sought. It was found that a correlation of overall noise and vibration levels was possible. Further, an even more obvious comparison was realized with the examination of one third octave frequency spectra of the two metrics. A discussion of vibration reduction measures is also included.

VIBRO-ACOUSTICS

The structure of a computer heat sink shroud can be modelled to represent a pulsating structure which displaces air from one side while drawing it in on the other. This is referred to as an acoustical dipole. The force required to move the shroud is related to the mass of the shroud itself as well as the added mass due to the reaction with the air. The sound radiation is representative of the force that is required to accelerate the added mass of the air.

Two mechanisms of excitation exist which can result in vibro-acoustic radiation. One is simple mechanical excitation from the movement of the fan. Sources can include the motor which can input mechanical energy into the system as can also the effects of a bad bearing or an unbalanced fan. The later is amongst the most common source of mechanical energy input. The second mechanism is the result of turbulence created by the passage of the fan blades that cause the air flow. When turbulence impinges on a body, a force is also exerted by the fluctuating components of the flow on the body and vice versa. This reaction force can also produce sound in the air.

VIBRATION MEASUREMENTS

For this investigation, vibration measurements of four fan sink designs were taken using a very small accelerometer placed at five locations on the heat-sink shroud at various operating speeds. A very low mass accelerometer is essential so as to not mass load the measured structure and by doing so, change it's mechanical properties. For this investigation, a sensor with a mass of 0.5 grams was used.

Using this procedure, un-weighted acceleration values (m/s^2) were recorded and further converted to un-weighted acceleration levels using the following equation with a reference value of 1.0e-5 m/s^2.

La (dB) = 20 x log10(a/1.0e-5)

Also presented are the 1/3 octave band data for the measured vibrations across the frequency range of 0 to 1000 Hz.

NOISE MEASUREMENTS

In addition to the vibration measurements, acoustic emissions of the computer cooling applications were also measured under the same operating conditions. To quantify the acoustic emissions of the fans, the emitted A-weighted sound pressure level at a distance of 0.5 meters was measured. All acoustic measurements were conducted in in a semi-anechoic room and in accordance to the standards of ECMA-74, ISO 7779 and ISO 3744.

RESULTS AND DISCUSSION

Figures 1, 2 and 3 illustrate the frequency spectra of the vibration acceleration, noise levels and vibration level for each of the four designs operating at the maximum speed.

Inspection of the vibration frequency spectra clearly show the locations of the fundamental and corresponding harmonics for each design. The reason for the non-corresponding locations for most of these peaks is that the maximum speed for each design operates at different RPMs. There are, however, harmonic similarities between the third and forth designs which are in fact also operate similarly. Design 3 though does exhibit greater harmonic energy at the lower frequencies and design 4 at the higher frequencies. This is more clearly illustrated in the graph of acceleration versus frequency given in Figure 3.

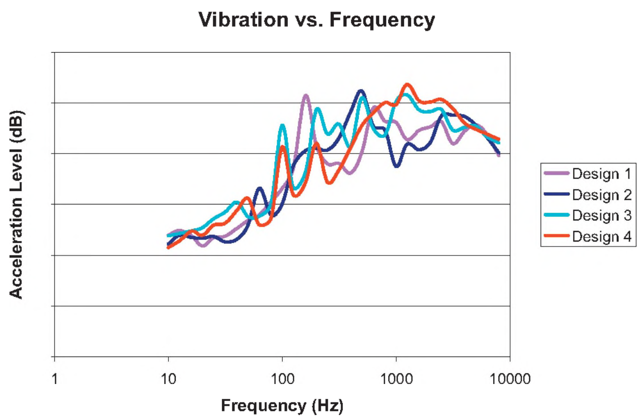

Figure 1: Graph of Frequency spectrum of Measured Vibration Level for Four Fan Designs

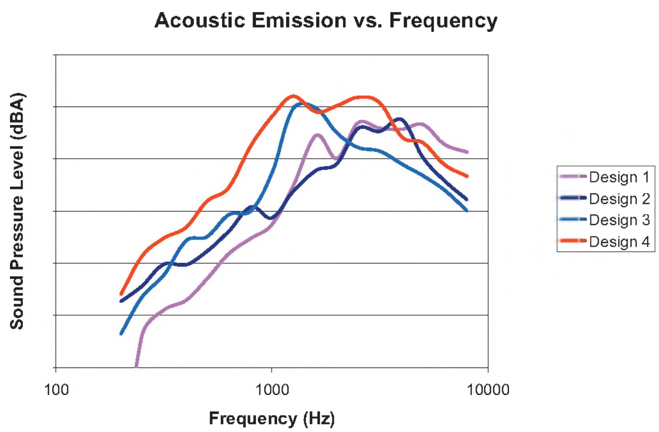

Figure 2: Graph of Frequency spectrum of Measured Acoustic Emission for Four Fan Designs

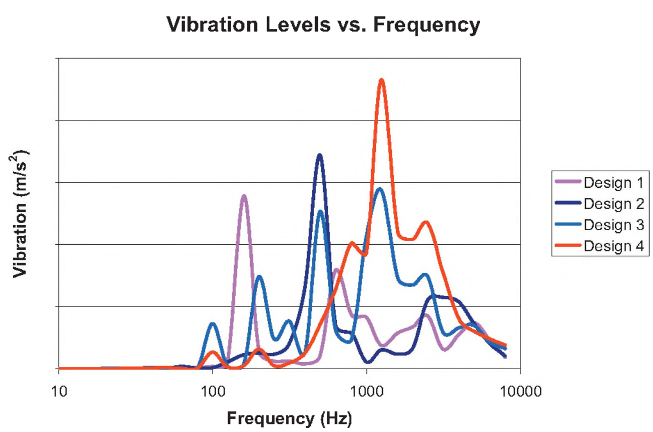

Figure 3: Graph of Frequency vs. Acceleration for Four Fan Designs

Inspection of the acoustic frequency plots in Figure 2 demonstrate much less defined responses with a clear lacking of predominate harmonics. This is indicative of the additional acoustic energy that is present in these measurements that can not be detected with a vibration sensor. Specifically, this spectra also includes the affect of flow noise mechanisms which would 'fill in the gaps' present in the vibration spectra and thus making meaningful correlation between the two difficult.

CONCLUSIONS

Several mechanisms for the generation of acoustic emissions exist which plague the designers of active cooling systems for state of the art video graphic cards. The fundamental noise generation is the result of aeroacoustic noise derived from the flow through the cooling system. The secondary noise source is structure borne noise from shell vibration. This vibration can be the result of either mechanical sources such as an unbalanced fan or flow induced from the presence of turbulent flow.

Four cooling designs were experimentally investigated for both noise and vibration. While useful information was derived from all of the measurement methods, a direct correlation between the noise and vibration data was difficult to obtain. This is due to the fact that the vibration measurements can predict the noise contribution from the vibration sources only. The noise measurement data showed the resulting noise from not only the vibrating sources, but also from any aeroacoustic generated noise. It should also be remembered that it is these flow induced noise sources that contribute most to the overall noise levels.

The vibration results did give some insight into some of the design properties. It was found that the designs which incorporated aluminum shrouds produced the greatest overall vibration levels when compared to the plastic directional shrouds.

In order to reduce the affects of vibration induced noise, several design criteria should be followed. Fans should be well balanced and of good mechanical design to avoid the creation of resonance into the structure. Air directional shrouds should be small as possible to minimize the acoustic radiation efficiency and made of materials that exhibit good damping properties. Care should also be taken to ensure that all locations of mounting are also appropriately isolated. This eliminates the transference of any mechanical energy to or from the computer chassis where it can be further amplified.